1. Afghanistan has approximately 7.8 million hectares (ha) of available cultivatable land (Koenig & Hunter, 1973, Ministry of Planning, 1961).

2. Prior to the war, of these 7.8 million ha, approximately 4.5 million ha were under annual crops. Further, between 50 and 60 percent of the 4.5 million ha producing annual crops were dedicated to wheat (Koenig & Hunter, 1973).

3. An analysis of area in wheat in Afghanistan as reported by multiple sources for the 1970s revealed that the area in wheat was relatively static. Using Afghan government statistics for groups of crops (Ministry of Planning, 1973), approximately 4.3 million ha were under annual crops. Fifty-five percent of this number is approximately 2.4 million ha which represents the area under wheat. The USDA estimate for that year (assumed to be based on Afghan government statistics) was approximately 2.35 million ha. This number serves as a general measure of results, but should not be considered authoritative, since its origins are believed to be highly subjective.

The procedure for the area analysis was as follows:

1. From expert opinion, it was determined that winter wheat generally occupies between 90 and 100 percent of the irrigated annual crop land (that not dedicated to horticulture). Other crops are rotated to the same land after the wheat harvest. During the springtime, therefore, wheat exists in almost a complete monoculture, except in specific areas dominated by other crops. For those provinces dominated by irrigated farming (as defined by expert opinion), the "total area of annual crops" as calculated from 1973 government statistics were taken, and multiplied by 0.9 to determine an available area in wheat in any "normal" year. In provinces for which other corollary information on general agricultural practices was available, this coefficient of irrigated wheat dominance was further reduced to represent as closely as possible expert opinion on the division between crops.

   Expert opinion indicated that rainfed (spring) wheat accounts for about 85 percent of the total crop area on the northern flank of the Hindu Kush mountain range in northern Afghanistan. For provinces completely within this zone of rainfed dominance, "normal" rainfed wheat was assumed to equal the total area of annual crop multiplied by 0.85; irrigated wheat area was assumed to equal total area multiplied by 0.05. In provinces divided by the boundary line between rainfed and irrigated wheat dominance, a hybrid factor representing the expected total was calculated.

2. According to expert opinion, "if water is available, there is (irrigated) wheat planted." The second coefficient was therefore established as a factor for the condition of irrigation or water delivery systems. Experts were questioned about damage or abandonment of irrigation systems on a province-by-province basis, and were asked to rate irrigation damage/abandonment on a scale of None, Slight, Moderate, or Severe. It has been reported (Azam Gul, 1982, 1984) that at the height of the war that area in wheat dropped an average of 67 percent, with the larger reductions in rainfed areas skewing the average. In irrigated-dominated provinces, a factor of 70 percent reduction was applied for a report of "Severe" damage to or abandonment of irrigation. A factor of 50 percent was used for a "Moderate" rating, and a 20 percent factor was used for a "Slight" rating. A "None" rating resulted in up to a 10 percent reduction for unaccounted damage, or reduction in area due to labor loss only.

In rainfed-dominated provinces, the percentage of total wheat area dedicated to rainfed and irrigated components was derived in the calculation of wheat dominance coefficients in Step 1. The percentage area reduction for water loss was applied only to the irrigated component of the total. For the rainfed portion of the total crop area, a different reduction was based upon other corollary reports as available. Such impacts included reports of severe population loss due to the war (theoretically resulting in reduction of planted area due to labor shortage) and reports of direct war damage to rainfed crops.

3. Competing crops: This coefficient was applied to account for the hectarage of specific competitive crops in specific areas. It was noted in the literature search and expert interviews that poppy competes for area with wheat, and that its phenology is similar to winter wheat (planted in the fall, harvested before wheat). Therefore, land dedicated to poppy is not available for wheat. Although poppy is interspersed with wheat throughout the country, it was felt that the reduction which occurred in Step 1 was sufficient to account for small plots. In certain areas, however, literature and expert sources indicated that poppy accounts for up to 50 percent of the available area. In these provinces, a calculation was first conducted to estimate the percentage of the total province affected. For example, it was reported that in the northern Helmand, poppy occupies up to 50 percent of the land. The northern Helmand represents approximately 70 percent of the total crop area of the province, so poppy occupies 50 percent of 70 percent of the total, or 35 percent of the total available area. The number arrived at in step 2 was therefore multiplied by 0.65 to account for poppy cultivation in Helmand.

In some rainfed areas, sources indicated increases in crops for horse fodder (barley, etc.) had occurred during the war years to facilitate transportation. In these provinces, therefore, a coefficient of competing crop was also applied to the rainfed wheat crop. Where no such reports occurred, this coefficient was equal to 1.00.

Provinces significantly affected by reported competing crops included Helmand, Qandahar, Oruzgan, Farah, Ningrehar, Paktia, Kunar, and Badakhshan (Poppy), and Lowgar (according to expert opinion, a single crop of corn is the dominant crop here).

4. The final output figures for each province were used to input to the CROPCAST model. In the model, further weighting was accomplished based upon expert opinion about the value of the crop in each province or aggregation of provinces.

5. The final output numbers were inserted into the model as an estimation of total area under wheat for the current year. The model combined area estimates with climatological parameters to arrive at yield estimates. When actual imagery became available, the area input number was revised based upon a traditional visual analysis of cultivated area.

The results of the preliminary wheat cultivation area assessment are shown in Tables 2-1A and 2-1B, along with the final estimates from analysis of satellite imagery. The preliminary coefficients described above for each province are presented in EarthSat's interim reports.

## 2.4 Area Assessment Using Satellite Imagery

The wheat area cultivation assessment performed by EarthSat represented the first nationwide objective assessment of agricultural area ever conducted. Approximately 50 percent of the country was imaged on six Landsat Thematic Mapper (TM) and seven Landsat Multi-Spectral Scanner (MSS) scenes, plus 17 Landsat TM image photomaps of southeastern Afghanistan prepared by EarthSat in the Agricultural Sector Support Program (ASSP) at 1:100,000 scale, which were also examined. Additionally, a single SPOT Multi-spectral (XS) image was acquired and processed over the rainfed-dominant area of the northern part of the country to examine the utility of this image type.

| PROVINCE | Early Est. AREA OF IRRIGATED WHEAT (Ha) | Early Est. ROUNDED TO NEAREST 10 HA | AREA OF IRRIGATED WHEAT (Ha) Calc. from Imagery | ROUNDED TO NEAREST 10 HA | CHANGE BETWEEN ESTIMATES (Ha) | PERCENT CHANGE FROM EARLY EST. (%) | EST. CHNG. FOR PROV. W/O IMAGERY (Mean for Region) | ESTIMATED AREA W/O IMAGERY (Ha) |
|---|---|---|---|---|---|---|---|---|
| WEST REGION | | | | | | | | |
| Herat | 242,847 | 242,850 | 126,067 | 126,070 | (116,780) | -48.087% | | |
| NORTHWEST REGION | | | | | | | | |
| Badghis | 6,583 | 6,580 | 39,180 | 39,180 | 32,600 | 495.441% | | |
| Farayab | 12,833 | 12,830 | 77,834 | 77,830 | 65,000 | 506.625% | | |
| Jowzjan | 25,791 | 25,790 | 71,977 | 71,980 | 46,190 | 179.100% | | |
| Balkh | 51,199 | 51,200 | 58,811 | 58,810 | 7,610 | 14.863% | | |
| Samangan | 72,319 | 72,320 | 15,457 | 15,460 | (56,860) | -78.623% | | |
| NORTH REGION | | | | | | | | |
| Baghlan | 74,027 | 74,030 | ---- | ---- | ---- | ---- | -21.205% | 58,332 |
| Kunduz | 101,996 | 102,000 | 122,220 | 122,220 | 20,220 | 19.824% | | |
| Takhar | 124,452 | 124,450 | 46,995 | 47,000 | (77,450) | -62.234% | | |
| NORTHEAST | | | | | | | | |
| Badakhshan | 37,156 | 37,160 | 11,440 | 11,440 | (25,720) | -69.214% | | |
| CENTRAL | | | | | | | | |
| Bamyan | 17,216 | 17,220 | 21,662 | 21,660 | 4,440 | 25.784% | | |
| Ghor | 70,807 | 70,810 | ---- | ---- | ---- | ---- | 25.784% | 89,068 |
| EAST CENTRAL | | | | | | | | |
| Parwan | 10,807 | 10,810 | 11,555 | 11,560 | 750 | 6.938% | | |
| Kapisa | 15,647 | 15,650 | 15,129 | 15,130 | (520) | -3.323% | | |
| Laghman | 14,493 | 14,490 | 18,305 | 18,310 | 3,820 | 26.363% | | |
| Kabul | 28,779 | 28,780 | 31,608 | 31,610 | 2,830 | 9.833% | | |
| Wardak | 13,340 | 13,340 | 36,407 | 36,410 | 23,070 | 172.939% | | |
| Lowgar | 5,205 | 5,210 | 3,826 | 3,830 | (1,380) | -26.488% | | |
| SOUTH CENTRAL | | | | | | | | |
| Oruzgan | 58,765 | 58,770 | 51,288 | 51,290 | (7,480) | -12.728% | | |
| Ghazni | 95,508 | 95,510 | 161,204 | 161,200 | 65,690 | 68.778% | | |
| Zabul | 42,233 | 42,230 | 32,024 | 32,020 | (10,210) | -24.177% | | |
| EAST | | | | | | | | |
| Ninghrehar | 26,370 | 26,370 | 37,232 | 37,230 | 10,860 | 41.183% | | |
| Kunar | 6,548 | 6,550 | 13,684 | 13,680 | 7,130 | 108.855% | | |
| Paktia/Paktika | 47,858 | 47,860 | 55,453 | 55,450 | 7,590 | 15.859% | | |
| SOUTHWEST | | | | | | | | |
| Kandahar | 29,201 | 29,200 | 106,314 | 106,310 | 77,110 | 264.075% | | |
| Helmand | 24,040 | 24,040 | 69,261 | 69,260 | 45,220 | 188.103% | | |
| Farah | 71,027 | 71,030 | 76,484 | 76,480 | 5,450 | 7.673% | | SUM |
| Nimruz | 123,397 | 123,400 | 23,433 | 23,430 | (99,970) | -81.013% | | 147,399 |
| TOTAL | 1,450,441 | 1,450,480 | 1,334,850 | 1,334,850 | 29,210 | 2.014% | | 167,710 (ROUNDED) |
| NATIONWIDE TOTAL includes Provinces w/o image coverage: | | | | 1,502,560 (incl. rounded sum to right) | | | | |

TABLE 2-1A. Afghanistan irrigated (winter) wheat area estimates (in hectares) for the 1989-90 growing season. The first two columns show the results of the preliminary estimate of irrigated wheat area prepared from analysis of historical data only (see Section 2.3). The second two columns show the final area estimates of irrigated wheat area based upon analysis of Landsat satellite imagery (see Section 2.4). The final four columns describe the percent change between the preliminary and final estimates, allowing an area estimate to be made for the two provinces without satellite image coverage (Baghlan and Ghor), based upon percent change by region.

| PROVINCE | Early Est. AREA OF RAINFED WHEAT (Ha) | Early Est. ROUNDED TO NEAREST 10 HA | AREA OF RAINFED WHEAT (Ha) Calc. from Imagery | ROUNDED TO NEAREST 10 HA | CHANGE BETWEEN ESTIMATES (Ha) | PERCENT CHANGE FROM EARLY EST. (%) | EST. CHNG. FOR PROV. W/O IMAGERY (Mean for Region) | ESTIMATED AREA W/O IMAGERY (Ha) |
|---|---|---|---|---|---|---|---|---|
| WEST REGION | | | | | | | | |
| Herat | 11,904 | 11,900 | 12,905 | 12,910 | 1,010 | 8.487% | | |
| NORTHWEST REGION | | | | | | | | |
| Badghis | 62,173 | 62,170 | 199,867 | 199,870 | 137,700 | 221.489% | | |
| Farayab | 144,936 | 144,940 | 159,284 | 159,280 | 14,340 | 9.894% | | |
| Jowzjan | 108,592 | 108,590 | 251,551 | 251,550 | 142,960 | 131.651% | | |
| Balkh | 129,345 | 129,350 | 120,481 | 120,480 | (8,870) | -6.857% | | |
| Samangan | 36,975 | 36,980 | 17,676 | 17,680 | (19,300) | -52.190% | | |
| NORTH REGION | | | | | | | | |
| Baghlan | 13,160 | 13,160 | ---- | ---- | ---- | ---- | -17.186% | 10,898 |
| Kunduz | 24,979 | 24,980 | 19,960 | 19,960 | (5,020) | -20.096% | | |
| Takhar | 112,353 | 112,350 | 96,314 | 96,310 | (16,040) | -14.277% | | |
| NORTHEAST | | | | | | | | |
| Badakhshan | 54,235 | 54,240 | 14,831 | 14,830 | (39,410) | -72.659% | | |
| CENTRAL | | | | | | | | |
| Bamyan | 4,023 | 4,020 | 0 | 0 | (4,020) | -100.000% | | |
| Ghor | 37,267 | 37,270 | ---- | ---- | ---- | ---- | Assume NC | 37,270 |
| EAST CENTRAL | | | | | | | | |
| Parwan | 636 | 640 | 0 | 0 | (640) | -100.000% | | |
| Kapisa | 0 | 0 | 0 | 0 | 0 | 0.000% | | |
| Laghman | 568 | 570 | 341 | 340 | (230) | -40.351% | | |
| Kabul | 1,568 | 1,570 | 339 | 240 | (1,330) | -84.713% | | |
| Wardak | 0 | 0 | 91 | 90 | 90 | ---- | | |
| Lowgar | 408 | 410 | 880 | 880 | 470 | 114.634% | | |
| SOUTH CENTRAL | | | | | | | | |
| Uruzghan | 9,000 | 9,000 | 1,116 | 1,120 | (7,880) | -87.556% | | |
| Ghazni | 5,571 | 5,570 | 4,442 | 4,440 | (1,130) | -20.287% | | |
| Zabul | 4,200 | 4,200 | 6,566 | 6,570 | 2,370 | 56.429% | | |
| EAST | | | | | | | | |
| Ninghrehar | 4,080 | 4,080 | 0 | 0 | (4,080) | -100.000% | | |
| Kunar | 1,310 | 1,310 | 131 | 130 | (1,180) | -90.076% | | |
| Paktia/Paktika | 4,523 | 4,520 | 1,818 | 1,820 | (2,700) | -59.735% | | |
| SOUTHWEST | | | | | | | | |
| Kandahar | 698 | 700 | 25,517 | 25,520 | 24,820 | 3545.714% | | |
| Helmand | 4,623 | 4,620 | 0 | 0 | (4,620) | -100.000% | | |
| Farah | 0 | 0 | 0 | 0 | 0 | 0.000% | | SUM |
| Nimruz | 0 | 0 | 0 | 0 | 0 | 0.000% | | 48,168 |
| TOTAL | 777,126 | 777,140 | 934,109 | 934,020 | 207,310 | 26.676% | | 48,170 (ROUNDED) |
| NATIONWIDE TOTAL includes Provinces w/o image coverage: | | | | 982,190 (Incl. Rounded Sum to Right) | | | | |

**TABLE 2-1B.** Afghanistan rainfed (spring) wheat area estimates (in hectares) for the 1990 growing season. The first two columns show the results of the preliminary estimate of rainfed wheat area prepared from analysis of historical data only (see Section 2.3). The second two columns show the final area estimates of rainfed wheat area based upon analysis of Landsat satellite imagery (see Section 2.4). The final four columns describe the percent change between the preliminary and final estimates, allowing an area estimate to be made for the two provinces without satellite image coverage (Baghlan and Ghor), based upon percent change by region. No change was made to the preliminary estimate for Ghor province due to the limited satellite coverage of the Central Region, resulting in a high percent change for Bamyan, the other province in the region (see Table 2).

### 2.4.1 Image Acquisition

Figure 2-1 shows the Landsat imagery of Afghanistan which was utilized in the analysis of wheat area. Initially, ten Landsat MSS scenes were ordered from the National Remote Sensing Agency (NRSA) of Hyderabad, India, from their ground station archive. The acquisition dates for seven of these scenes ranged from 2 April to 6 May 1990. Three Path/Rows without spring 1990 coverage were ordered from the spring of 1989. Unfortunately, five of the original ten MSS scenes were canceled due to "technical reasons" by NRSA. Five replacement MSS scenes were ordered, but three of the five were again canceled. A total of seven MSS scenes were ultimately received and analyzed.

Because of the difficulties in acquiring the desired MSS imagery from NRSA, it was decided to additionally examine the Landsat image archive of the Earth Observation Satellite Company (EOSAT) of Lanham, Maryland for satisfactory coverage of western Afghanistan. Five EOSAT Landsat TM scenes were selected and acquired from the spring of 1990 to supplement the Indian MSS data. One TM scene utilized in the ASSP program was also processed as a full scene product for the Afghan CROPCAST program. The project TM coverage is also shown in Figure 2-1.

Images were ordered in digital format on Computer Compatible Tapes (CCTs). All scenes ordered from EOSAT were received within two weeks of order; the MSS scenes from NRSA took much longer to arrive, up to 16 weeks from the time of order.

Due to the cancellation of MSS scene orders over eastern Afghanistan by NRSA, and the inability of EOSAT to acquire Landsat imagery over that region (also for technical reasons) 17 Landsat TM image maps covering southeast Afghanistan at 1:100,000 scale, prepared for the ASSP program, were utilized for agriculture interpretation over this area. Although the majority of TM imagery used in the production of these image maps was acquired in 1989, the assumption was made that no major changes in area occurred between 1989 and 1990. Finally, a digital mosaic of the

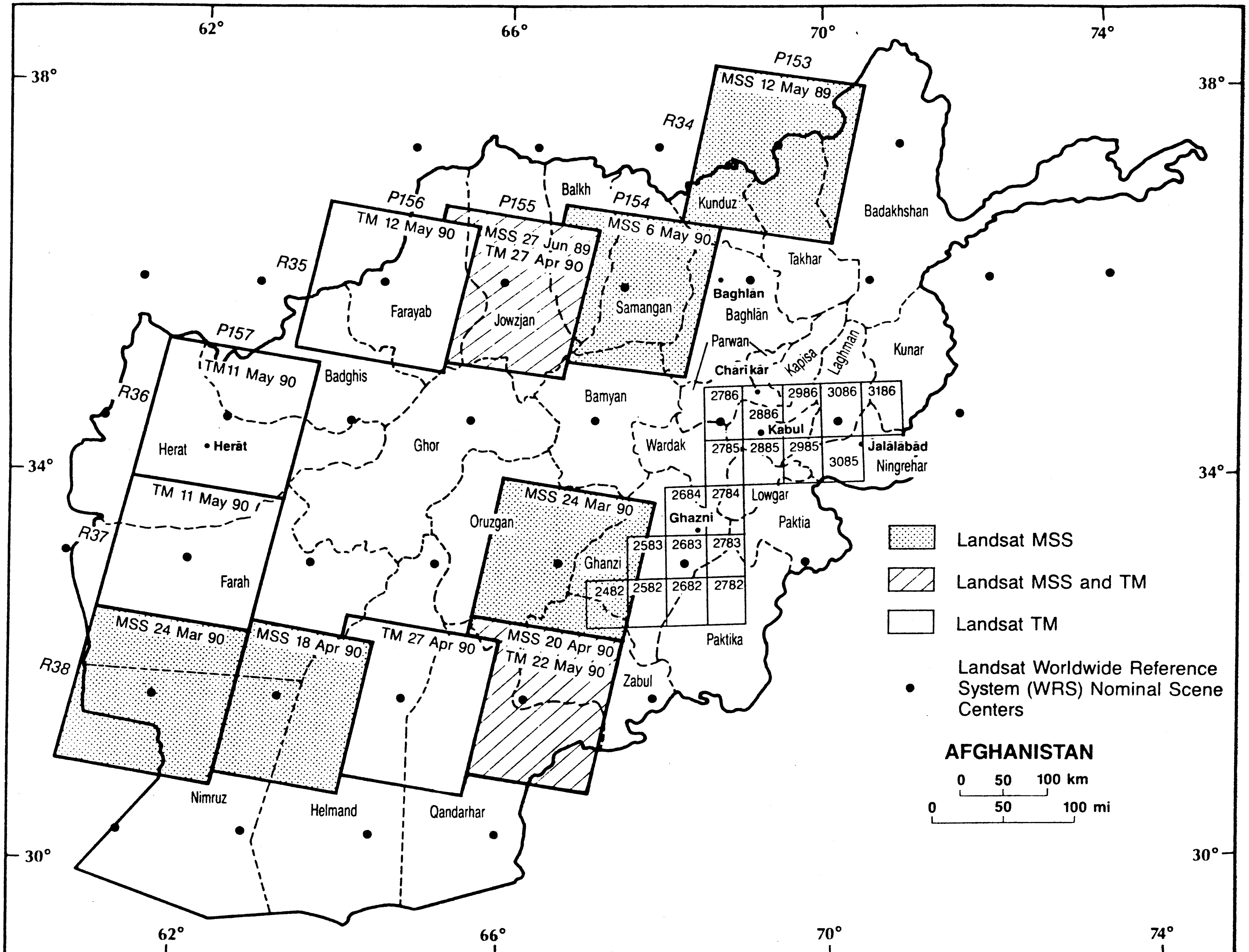


**FIGURE 2-1.** Coverage of Landsat full-scene and TM image maps.

imagery used to create the ASSP image maps was employed to analyze agricultural area for important areas not covered by any of the above sources, including Kunar, Laghman, Kapisa, Parwan, Wardak, and Paktia/Paktika[1] provinces.

### 2.4.2 Image Processing

The received images were processed on EarthSat's Sun 4 image processing system, using proprietary enhancement software to minimize image "noise" and distortion, and to maximize visual content. All Landsat TM imagery was processed using a band 3-7-4 combination, with red visible light (0.63-0.69 um), middle infrared (2.08-2.35 um), and near infrared energy (0.76-0.90 um) being shown on the final image in blue, green, and red, respectively. This band combination has proven useful in previous work in Africa and South America in minimizing atmospheric haze, while presenting a color appearance similar to standard false-color infrared. The Landsat MSS images were processed in a band 1-2-4 combination, with green visible light (0.5-0.6 um), red visible light (0.6-0.7 um), and upper near infrared reflected energy (0.8-1.1 um) being shown on the final image in blue, green, and red, respectively. This band combination is referred to as a standard false-color image, with healthy vegetation appearing in red due to the dominance of chlorophyll. Both band combinations feature healthy agricultural vegetation in brighter shades of red. Since the human eye is able to distinguish many more hues of red than green, the red-dominated false-color images were used for crop area delineation. Plates 1 through 13 in Appendix A show contact color prints of each of the TM and MSS full-scene images used in the project. Plate 14 presents an example of a 1:100,000 scale ASSP map sheet similar to those utilized in the southeastern portion of the country.

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[1] Historical crop area sources utilized in the generation of the preliminary crop area statistics listed only one province in this area, "Paktya." Examination of maps in Dupree (1973) suggested that the two provinces of Paktia and Paktika may have been a single province at one time. Thus, for the preliminary estimate, the two modern provinces were combined for all calculations. For consistency, this combination was carried over into the final area assessment using Landsat imagery.

Where 1:100,000 scale topographic base maps of Afghanistan were available, Landsat TM images were geocoded to this map base to provide an accurate means of location of province and national boundaries, and for the selection of field sample sites.

All Landsat full scene imagery was enlarged in EarthSat's photographic laboratory to 1:250,000 scale for interpretation compilation, and 1:100,000 scale for detailed analysis. The ASSP image maps were prepared at their standard scale of 1:100,000.

### 2.4.3 Image Interpretation

Clear acetate overlays were attached and registered to each 1:250,000 scale image and 1:100,000 scale image map. Adjacent full scene images were compared, and areas of overlap were delimited to prevent dual interpretation of areas on two scenes. Interpretation of the imagery then began using the following legend:

| | |
|---|---|
| **A1** | Active Irrigated Agriculture |
| **A2** | Active Rainfed Agriculture |
| **B** | Inactive Agriculture (fallow or abandoned) |
| **X** | Non-Agriculture |
| **W** | Cloud Cover (no interpretation possible) |

A minimum mapping unit of one-half kilometer squared was employed. Inactive agriculture was differentiated from active only in those areas where this minimum mapping unit was met. Since ground truth to accompany image interpretation was not available, no attempt was made to differentiate wheat from other crops in visual interpretation. Instead, a total area was developed for area in active agriculture, and this figure was statistically reduced to arrive at a wheat estimate. This activity is discussed in Section 2.4.4.

All interpretations were edited by a separate interpreter for accuracy, line closure, proper labeling, and edge match to surrounding images.

### 2.4.4 Agriculture Area Assessment

Provincial boundaries were transferred to the interpretation image overlays from map sources. The overlays were then digitized into GIS coverages using a PC-based ARC/INFO system. Since portions of several provinces were usually present on each image or image map overlay, a data base was developed which allowed the summation of the total area examined from each province on an image-by-image basis. For each province, the following variables were created:

1. Total area of active irrigated agriculture (A1) measured
2. Total area of active rainfed agriculture (A2) measured
3. Total area of inactive agriculture (B) measured
4. Total area of cloud cover (W) measured (not included in image totals)
5. Total area of non-agriculture (X) measured
6. Total area of province reviewed on image (A1 + A2 + B + X)
7. Total area of province (from tables provided by DAI)

For each province, a percentage of the total province area examined was calculated from the above variables:

Percent of Province Reviewed = (A1 + A2 + B + X)/Total Province Area

The results for each province observed were totaled, and figures were calculated for each of the above variables to arrive at total values for each category observed. The total percentage of the province interpreted was also summed. Tables 2-2A and 2-2B show these absolute numbers for irrigated and rainfed wheat, respectively. Once these absolute numbers were determined, the following regression was performed to account for non-wheat inclusions in the interpreted crop areas, and to account for the portion of each province not examined on imagery.

1. A percentage of the total cultivation area in the province covered by the analysis was calculated using the percentage of province area covered, as modified by an estimation of agricultural distribution in the province versus image coverage. For example, approximately 72 percent of the province of Herat was included on Landsat TM imagery; however, based upon the literature research at the beginning of the program, it was estimated that approximately 85 percent of the significant irrigated cultivation areas of the province were imaged and analyzed. Category A1 was therefore increased from its measured amount to a figure

# 1.0 INTRODUCTION AND BACKGROUND

## 1.1 Project Introduction

The climate in Afghanistan (both politically and climatologically) has resulted in wheat production estimates that are often untimely and unreliable. Since 1978, Afghan crop data sources have been subject to severe distortions for a variety of reasons. This has produced a shortfall in information for which the Office of the United States Agency for International Development Representative (AIDREP) has had to rely in preparing its plan for the food security activities for Afghanistan.

The CROPCAST™ approach to monitoring crop production has offered a solution to the lack of timely and reliable information within the country. The CROPCAST system provides a mechanism for providing wheat production estimates during the growing season sufficiently in advance to allow AIDREP to plan its food security program activities to be effective. Thus, CROPCAST was employed under subcontract to Development Alternatives, Inc. (DAI) under DAI contract 304-0204-C-00-9829-00 to provide wheat production estimates for the 1990 growing season.

The primary objectives of this sub-contract were:

1. to determine the amount of land under cultivation in wheat grain and quality of crop for the entire country;

2. estimate the annual percent of change to determine increase or decrease in land under cultivation and quality of crop; and

3. provide province-level crop (wheat) production estimates for Afghanistan.

The following sections of this report summarize our efforts during the first year of the contract. Section 1.2 provides background on the CROPCAST system and its applicability to Afghanistan. Section 2.0 details the 1990 area estimation process, Section 3.0, details the wheat yield process and presents the summary production estimates for 1990. Section 3.0 also provides a discussion of the integration of CROPCAST activities into crop suitability assessments on a Geographic Information

representing 100 percent of the total irrigated area. A similar calculation was conducted for rainfed agriculture. This calculation yielded two values: Total Agricultural Area (Irrigated) ($TAA_I$), and Total Agricultural Area (Rainfed) ($TAA_R$). These figures are shown by province in Tables 2-2A and 2-2B, respectively.

2. The total areas for irrigated and rainfed wheat ($A_{IW}$ and $A_{RW}$ respectively) were calculated using a reduction coefficient for crop dominance and non-agricultural inclusions based upon literature search, examination of imagery, and expert information:

$$A_{IW} = TAA_I * C_C$$
$$A_{RW} = TAA_R * C_C * C_U$$

Where:

| | | |
|---|---|---|
| $A_{IW}$ | = | Area of Irrigated Wheat |
| $A_{RW}$ | = | Area of Rainfed Wheat |
| $TAA_I$ | = | Total Irrigated Agriculture Area |
| $TAA_R$ | = | Total Rainfed Agriculture Area |
| $C_C$ | = | Coefficient of Competing Crops |
| $C_U$ | = | Coefficient of Rainfed Land Usage |

The values for competing crops ($C_c$) in each category were calculated in a fashion similar to that described in Section 2.3, except that this coefficient represented a combination of the earlier measure of wheat dominance and competing crop. The value for the coefficient of rainfed land usage was approximated by a visual assessment of rainfed agriculture usage within those areas labeled A2 on the imagery. This was done to account for observed inclusions of non-cultivation too small to be delineated in rainfed areas. The calculated values for the above coefficients and variables are also shown in Tables 2-2A and 2-2B.

3. Only two provinces (Baghlan and Ghor) completely lacked satellite image coverage. In these provinces, the average percent change in area from the preliminary (non-image) estimation to the final (image area) estimation was calculated for provinces from the same region with image coverage. The original estimate calculated from non-image information was then altered by that average.

The final crop area numbers were provided for input into the CROPCAST model for integration with the yield calculation described in Section 3.0.

| PROVINCE | Irrigated Ag. Area Direct Measurement from Images A1 (Ha) | Percent Province Viewed (Absolute) (Decimal) (%/100) | Estimated Percent of Irr. Ag. Area (Decimal) (AV) | Projected Total Area (Ha) of Irr. Ag. A1/AV (TAAI) | Coeff. of Competing Crop (Decimal) (CC) | PROJECTED TOTAL AREA (Ha) IRRIGATED WHEAT (AIW=TAAI*CC) | TOTAL ROUNDED TO NEAREST 10 Ha | REGION SUMMARY (Ha) |
|---|---|---|---|---|---|---|---|---|
| WEST REGION | | | | | | | | |
| Herat | 119,063 | 0.718 | 0.850 | 140,074 | 0.90 | 126,067 | 126,070 | 126,070 |
| NORTHWEST REGION | | | | | | | | |
| Badghis | 34,571 | 0.617 | 0.750 | 46,095 | 0.85 | 39,180 | 39,180 | |
| Farayab | 88,822 | 0.946 | 0.970 | 91,569 | 0.85 | 77,834 | 77,830 | |
| Jowzjan | 71,977 | 0.694 | 0.800 | 89,971 | 0.80 | 71,977 | 71,980 | |
| Balkh | 58,811 | 0.725 | 0.850 | 69,189 | 0.85 | 58,811 | 58,810 | |
| Samangan | 22,890 | 0.962 | 0.970 | 23,598 | 0.66 | 15,457 | 15,460 | 263,260 |
| NORTH REGION | | | | | | | | |
| Baghlan | ---- | (No Observation) | | | | 58,332* | 58,330 | |
| Kunduz | 43,650 | 0.260 | 0.250 | 174,600 | 0.70 | 122,220 | 122,220 | |
| Takhar | 44,231 | 0.497 | 0.800 | 55,289 | 0.85 | 46,995 | 47,000 | 227,550 |
| NORTHEAST | | | | | | | | |
| Badakhshan | 6,435 | 0.132 | 0.450 | 14,300 | 0.80 | 11,440 | 11,440 | 11,440 |
| CENTRAL | | | | | | | | |
| Bamyan | 5,097 | 0.121 | 0.200 | 25,485 | 0.85 | 21,662 | 21,660 | |
| Ghor | ---- | (No Observation) | | | | 89,068* | 89,070 | 110,730 |
| EAST CENTRAL | | | | | | | | |
| Parwan | 10,196 | 0.458 | 0.750 | 13,595 | 0.85 | 11,555 | 11,560 | |
| Kapisa | 11,569 | 0.188 | 0.650 | 17,798 | 0.85 | 15,129 | 15,130 | |
| Laghman | 22,228 | 0.464 | 0.850 | 26,151 | 0.70 | 18,305 | 18,310 | |
| Kabul | 37,186 | 1.000 | 1.000 | 37,186 | 0.85 | 31,608 | 31,610 | |
| Wardak | 25,699 | 0.387 | 0.600 | 42,832 | 0.85 | 36,407 | 36,410 | |
| Lowgar | 19,130 | 1.000 | 1.000 | 19,130 | 0.20 | 3,826 | 3,830 | 116,850 |
| SOUTH CENTRAL | | | | | | | | |
| Oruzgan | 46,625 | 0.655 | 0.750 | 62,167 | 0.83 | 51,288 | 51,290 | |
| Ghazni | 170,687 | 0.734 | 0.900 | 189,652 | 0.85 | 161,204 | 161,200 | |
| Zabul | 35,791 | 0.670 | 0.950 | 37,675 | 0.85 | 32,024 | 32,020 | 244,510 |
| EAST | | | | | | | | |
| Ninghrehar | 40,335 | 0.559 | 0.650 | 62,054 | 0.60 | 37,232 | 37,230 | |
| Kunar | 8,797 | 0.152 | 0.450 | 19,549 | 0.70 | 13,684 | 13,680 | |
| Paktia/Paktika | 52,191 | 0.533 | 0.800 | 65,239 | 0.85 | 55,453 | 55,450 | 106,360 |
| SOUTHWEST | | | | | | | | |
| Kandahar | 115,280 | 0.531 | 0.900 | 128,089 | 0.83 | 106,314 | 106,310 | |
| Helmand | 71,649 | 0.372 | 0.750 | 95,532 | 0.73 | 69,261 | 69,260 | |
| Farah | 66,508 | 0.617 | 0.800 | 83,135 | 0.92 | 76,484 | 76,480 | |
| Nimruz | 16,033 | 0.578 | 0.650 | 24,666 | 0.95 | 23,433 | 23,430 | 275,480 |
| TOTAL | 1,245,451 | | | 1,654,619 | | 1,482,250 Measured Total | 1,482,250 Rounded Total | |

TABLE 2-2A. Calculation of irrigated (winter) wheat area for the 1989-90 growing season, based upon analysis of Landsat satellite imagery. Due to lack of satellite image coverage, the total irrigated wheat areas for Baghlan and Ghor provinces (*) are derived from the preliminary wheat area estimates as described in Section 2.3 (see table 1A).

| PROVINCE | Rainfed Ag. Area Direct Measurement from Images A2 (Ha) | Percent Province Viewed (Absolute) (Decimal) (%/100) | Estimated Percent Rainfed Ag. Area (Decimal) (AV) | Total Area (Ha) of RF Ag. A2/AV (TAAR) | Coeff. of Competing Crop (Decimal) (CC) | Coeff. of Rainfed Useage (Decimal) (CU) | TOTAL AREA (Ha) RAINFED WHEAT (ARW=TAAR*CC*CU) | TOTAL ROUNDED TO NEAREST 10 Ha | REGION SUMMARY (Ha) |
|---|---|---|---|---|---|---|---|---|---|
| WEST REGION | | | | | | | | | |
| Herat | 34,414 | 0.718 | 0.800 | 43,018 | 0.60 | 0.50 | 12,905 | 12,910 | 12,910 |
| NORTHWEST REGION | | | | | | | | | |
| Badghis | 340,682 | 0.617 | 0.750 | 454,243 | 0.80 | 0.55 | 199,867 | 199,870 | |
| Farayab | 321,886 | 0.946 | 0.970 | 331,841 | 0.80 | 0.60 | 159,284 | 159,280 | |
| Jowzjan | 362,814 | 0.694 | 0.750 | 483,752 | 0.80 | 0.65 | 251,551 | 251,550 | |
| Balkh | 284,468 | 0.725 | 0.850 | 334,668 | 0.80 | 0.45 | 120,481 | 120,480 | |
| Samangan | 47,626 | 0.962 | 0.970 | 49,099 | 0.80 | 0.45 | 17,676 | 17,680 | 748,860 |
| NORTH REGION | | | | | | | | | |
| Baghlan | ---- | (No Observation) | | | | | 10,898* | 10,900 | |
| Kunduz | 9,980 | 0.260 | 0.200 | 49,900 | 0.80 | 0.50 | 19,960 | 19,960 | |
| Takhar | 229,320 | 0.497 | 0.750 | 305,760 | 0.70 | 0.45 | 96,314 | 96,310 | 127,170 |
| NORTHEAST | | | | | | | | | |
| Badakhshan | 18,254 | 0.132 | 0.400 | 45,635 | 0.65 | 0.50 | 14,831 | 14,830 | 14,830 |
| CENTRAL | | | | | | | | | |
| Bamyan | 0 | 0.121 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | |
| Ghor | ---- | (No Observation) | | | | | 37,270* | 37,270 | 37,270 |
| EAST CENTRAL | | | | | | | | | |
| Parwan | 0 | 0.458 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | |
| Kapisa | 0 | 0.188 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | |
| Laghman | 690 | 0.464 | 0.850 | 812 | 0.70 | 0.60 | 341 | 340 | |
| Kabul | 806 | 1.000 | 1.000 | 806 | 0.70 | 0.60 | 339 | 240 | |
| Wardak | 87 | 0.387 | 0.400 | 218 | 0.70 | 0.60 | 91 | 90 | |
| Lowgar | 9,773 | 1.000 | 1.000 | 9,773 | 0.15 | 0.60 | 880 | 880 | 1,550 |
| SOUTH CENTRAL | | | | | | | | | |
| Oruzgan | 1,145 | 0.655 | 0.400 | 2,863 | 0.65 | 0.60 | 1,116 | 1,120 | |
| Ghazni | 9,692 | 0.734 | 0.900 | 10,769 | 0.75 | 0.55 | 4,442 | 4,440 | |
| Zabul | 13,861 | 0.670 | 0.950 | 14,591 | 0.75 | 0.60 | 6,566 | 6,570 | 12,130 |
| EAST | | | | | | | | | |
| Ninghrehar | 0 | 0.559 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | |
| Kunar | 140 | 0.152 | 0.450 | 311 | 0.70 | 0.60 | 131 | 130 | |
| Paktia/Paktika | 3,729 | 0.533 | 0.800 | 4,661 | 0.65 | 0.60 | 1,818 | 1,820 | 1,950 |
| SOUTHWEST | | | | | | | | | |
| Kandahar | 66,003 | 0.531 | 0.970 | 68,044 | 0.75 | 0.50 | 25,517 | 25,520 | |
| Helmand | 0 | 0.372 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | |
| Farah | 0 | 0.617 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | |
| Nimruz | 0 | 0.578 | 1.000 | 0 | 0.00 | 0.00 | 0 | 0 | 25,520 |
| TOTAL | 1,755,370 | | | 2,210,762 | | | 982,277 Measured Total | 982,190 Rounded Total | |

TABLE 2-2B. Calculation of rainfed (spring) wheat area for the 1990 growing season, based upon analysis of Landsat satellite imagery. Due to lack of satellite image coverage, the total rainfed wheat areas for Baghlan and Ghor provinces (*) are derived from the preliminary wheat area estimates as described in Section 2.3 (see table 1A).

## 2.5 General Observations from Image Analysis

During the course of image interpretation, several observations were made concerning the utility of image sources, the ease of their use, and the degree to which these observations supported or denied literature sources and expert opinion. These observations are summarized in the following subsections.

### 2.5.1 Applicability of Image Types to Agricultural Area Analysis

Although both MSS and TM imagery were utilized in this project, it was observed that the large pixel size (80 meters vs. 30 meters) and wide spectral band widths of MSS made this sensor less desirable for detailed analysis of crop area. Additionally, difficulties in acquiring MSS imagery from NRSA in Hyderabad, India, also suggest that TM is the more utile Landsat image sensor for future analyses in Afghanistan.

The SPOT-XS scene examined revealed an even greater improvement in the ability to separate agricultural fields from the image background. However, the limited spectral capabilities (three reflective bands vs. TM's six), and the high cost of SPOT imagery per square kilometer versus Landsat makes SPOT imagery less cost-effective[2] in a large-area program. However, SPOT-XS imagery would be useful both for interpreter training and for detailed analysis of specific areas, especially if acquired near the same time as accompanying TM imagery of the same location. In effect, SPOT-XS imagery may represent the closest approximation to "ground truth" possible in the commercial world in Afghanistan, given the current political situation.

There is a further potential application for the use of SPOT-Panchromatic (SPOT-P) data (10 meter resolution in a single wide spectral band, 0.51 to 0.73 um) in the

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2 A single Landsat TM image covers an area about 185 by 170 kilometers (about 31,450 km$^2$). A single SPOT image acquired in a near-vertical orientation covers only about 60 by 60 kilometers (3,600 km$^2$), or about one-ninth the total area of a Landsat TM scene. SPOT XS data cost almost half as much as a full scene of TM data; processing costs for SPOT-XS are also about half as much as TM. In total, acquisition and processing of a Landsat TM full scene costs about \$ 0.19 per square kilometer covered, versus about \$ 0.95 per square kilometer for SPOT-XS.

preparation of summary and briefing products in which the high spatial resolution capabilities of SPOT-P are combined with the spectral capabilities of Landsat TM.

The wide differences between the preliminary and final area estimates suggest that there would be high utility in conducting a nationwide inventory of agriculture from satellite imagery at least once, to provide a completely objective area baseline against which to measure area changes. Imagery for this procedure should be acquired from a single growing season, and should be Landsat TM, possibly supplemented with SPOT-XS in selected mountainous areas where small field size will be a problem.

Given the minimal amount of significant agriculture apparent in some portions of the country examined in this study, it is recommended that once a nationwide inventory of agriculture is conducted, succeeding crop yield forecasts should be based upon analyses of more limited areas, primarily in Ghazni, Qandahar, Helmand, Jowzjan/Farayab, and Kunduz/Baghlan. This will reduce the amount of imagery to be acquired, processed, and interpreted, and will allow the acquisition of higher resolution Landsat TM imagery in place of a larger number of lower-resolution MSS images.

### 2.5.2 Correlation Between Expert Opinion and Image Observations

Prior to the beginning of image analysis, there was no means of confirming reports of damage, water shortage, or pestilence from expert or literature sources. During image analysis, however, several conclusions were able to be drawn concerning the reliability of the sources.

Both experts interviewed and literature sources mentioned problems in northern Afghanistan with locusts and sunn pests. Landsat TM and MSS images (Plates 2, 6, 7, 9, and 11 in Appendix A) acquired over the northern tier of provinces revealed very large areas of cropland (as defined by the presence of field patterns) without cultivation. The reports of pestilence devastation in these areas were therefore considered reliable.

Both expert opinion and literature sources indicated that active agricultural area would decrease with refugee movements from an area, due to a decrease in labor supply. Although there was not multi-year imagery to analyze crop area increases or decreases over time, large amounts of inactive agricultural land were observed in Qandahar, Helmand, Ghazni, and Herat provinces, all of which were reported to have over 50 percent of their population registered out-of-country as refugees. However, it appeared that war damage to water supplies was overstated by expert opinion, as water levels in rivers and reservoirs appeared to be abundant, and in these areas, there was a great deal of active cultivation.

Although all experts questioned reported a crop rotation in most irrigated areas (winter wheat followed by other crops), the agricultural statistics and written literature sources suggested that areas for each type of crop were exclusive of each other. The statistics for area in wheat generated in this study assume a virtual winter wheat monoculture, except in areas with documented levels of other specific cropping practices (e.g., single-crop corn dominance in Lowgar Province; horticultural activity in Qandahar and Ningrehar Provinces, etc.). The coefficients of competing crop, actually expressed in terms of wheat dominance, varied from 60 to 95 percent for winter (irrigated) wheat, except in Lowgar (20 percent), and from 60 to 80 percent for spring (rainfed) wheat, again except for Lowgar (15 percent), and for provinces with no reported rainfed agriculture (0.00), mainly in the desert southwest.

### 2.5.3 Extent of Satellite Image Coverage

The wheat area estimates for this program were based upon an absolute measurement of cultivated area visible on satellite images, which were then extrapolated to account for areas not covered by imagery, which were then reduced by observations of non-agricultural inclusion and knowledge of mixed cropping practices for specific provinces. While general information was available on the types of farming to be expected in non-imaged areas (irrigated vs. rainfed), information on spatial distribution of agriculture was limited to nationwide maps. Thus, the estimated percentage of

significant crop area viewed for any given province (Tables 2-2A and 2-2B; variable AV) is subjective. With the exception of Helmand, coefficients in provinces with less than 50 percent absolute image coverage have room for significant improvement in subsequent years.

Where other estimates of Afghan wheat area begin with an assumption of area of annual crop land nationwide, and then reduce that area to account for various other crops (making an assumption of exclusivity of cropland use), the CROPCAST estimate began with a more objective measure of total annual crop area. Even so, the Landsat image coverage of the country was far from complete (Figure 2-1), and assumptions about crop area distribution in the non-imaged areas had to be made. A very small percentage of some provinces was imaged, adding to concern for the validity of area estimates. These points suggest the need for a completely contiguous analysis of crop area in the future, to provide a totally objective view of total agricultural area for future analysis.

## 3.0 CROP YIELD ESTIMATION

The yield estimation process involved three phases. The first phase was to calculate provincial base yields from which model adjustments could be made. The second phase was (and is) a daily operational activity of monitoring wheat yield and condition. The third phase is an ongoing calibration which is implemented to provide accuracy improvements. These processes will be described more completely in the following sections.

### 3.1 Calculation of Provincial Base Yields

Four assumptions were made in the calculation of base yields for irrigated and non-irrigated wheat at the provincial level for Afghanistan. These four assumptions were:

1. There has been no technological trend in yields since the mid 1970's.

2. The normal national base yield is 1250 kilograms per hectare.

3. Base yields for irrigated wheat average twice the base yields for rainfed wheat for each province.

4. Factors that affect the deviation from base yields are soil type, fertilizer usage, irrigation availability, and environmental factors such as rainfall, evapotranspiration, and pests.

The assumption that there has been no technological trend in yields since 1970 is based on evaluation of the results of existing data sources of national yield and expert opinion obtained in the first phases of the project. Yield data obtained since 1978 were viewed as being of questionable accuracy, and were not used.

The assumption that a normal national base yield is approximately 1250 kilograms per hectare was derived from an analysis of the growing conditions for the period 1973-1978 and reported yields from the Afghan Ministry of Planning and Statistics. Growing conditions during this period were analyzed as being slightly below normal, so the normal yield was above the average yield for the period.

The assumption that base yields for irrigated wheat are two times the yields for rainfed wheat are based on an analysis of data sources obtained from the University of Nebraska at Omaha, and expert opinion. The Swedish Committee report was also reviewed after this assumption was made. Although the Swedish yield data were not utilized directly, they did seem to confirm the assumption regarding the yield relationships between irrigated and rainfed wheat.

Assumptions on the parameters used for adjusting the base yields were based on the experience of the CROPCAST modelers in similar growing regions and expert opinions as to the critical factors causing yield deviations in Afghan wheat agriculture.

The equations employed for the calculation of the base yields are:

Total Production = Aiw * (X1*Irf) + Arw * (X2*Rrf)

Base Yield * ADJ = (BI * X1) + (BR * X2)

assuming X1 = 2.0 * X2

Where:

| | | |
|---|---|---|
| Base Yield | = | 1250 kg/h |
| ADJ | = | (CFsoil + CFfert + CF%irr) + 1.0 |
| CFsoil | = | Correction factor for soil type |
| CFfert | = | Correction factor for fertilizer availability |
| CF%irr | = | Correction factor for percentage of irrigated land |
| Aiw | = | Irrigated wheat area |
| Arw | = | Rainfed wheat area |
| Irf | = | Reduction factor for irrigated wheat |
| Rrf | = | Reduction factor for rainfed wheat |
| BI | = | Percentage of irrigated acreage |
| BR | = | Percentage of rainfed acreage |
| X1 | = | Adjusted base yield for irrigated wheat |
| X2 | = | Adjusted base yield for rainfed wheat. |

The correction factors (CF's) used in the calculation of the adjustment (ADJ) to the base yields required, are defined as follows:

| | |
|---|---|
| CFsoil = | +0.20 Very Good soils |
| | +0.15 Good soils |
| | +0.10 Above Average + |
| | +0.05 Above Average - |
| | 0.00 Average |
| | -0.05 Below Average + |
| | -0.10 Below Average - |
| | -0.15 Poor soils |
| | -0.20 Very poor soils present |
| CFfert = | +0.10 Above normal usage |
| | +0.05 Normal/(<10% below normal) |
| | -0.10 10 - 30% Below normal |
| | -0.15 31 - 70% Below normal |
| | -0.20 71 - 100% Below normal |
| CF%irr = | 0.00 < = 50% Irrigated land |
| | +0.10 51 - 75% Irrigated land |
| | +0.20 76 - 90% Irrigated land |
| | +0.30 91 - 100% Irrigated land |

The assumptions made in defining these criteria were that "good" natural soils and application of fertilizer would necessarily produce increased yield in the crop grown. The correction factor for percent of irrigated land (CF%irr) was employed to minimize the effect to base yield that weather related stresses, (i.e. drought, high temperatures, pests, etc.) have in areas with a large percentage of irrigated land as opposed to areas with a large percentage of rainfed land, (i.e. weather stresses have a greater adverse effect on rainfed crops than irrigated crops).

From the set of correction factors a provincial base yield for irrigated and rainfed wheat was computed to provide an estimate of the crop yield for a "normal year". The provincial base yields were themselves modified according to sets of reduction factors in order to obtain initial yield estimates for the year 1990.

The individual correction factors employed in the calculation of provincial base yields were obtained from both historical data and expert opinion. The correction factor for fertilizer usage was determined from data published by the Swedish Committee for Afghanistan Fourth Report (1990), which outlined the relative percentages of fertilizer

System (GIS). Section 4.0 presents a preliminary look at conditions evolving for the 1991 crop, and Section 5.0 presents a summary of project findings and recommendations for year-two efforts.

## 1.2 The CROPCAST System

The CROPCAST System is uniquely different from other agrometeorological modeling efforts in its use of meteorological satellite data to gain a description of the total spatial variance of the weather factors that affect crop production. The evaluation of timely weather information; i.e., at 6-hourly and 24-hourly periods, provide the temporal assessment of weather/plant relationships relating to the specific plant growth stage.

The data continuum is organized on a global grid reference system at a resolution of 48 kilometers. At this resolution plant weather diagnoses are accomplished for 100 percent of the producing area every six hours. Daily assessments of plant growth and stress factors are then made over a sample of 12.5 x 12.5 km cells. The samples are centered in the primary production areas. The grid reference is also used to store and access soils, tillage information, and climatology. The integration of meteorological satellite data with ground-based meteorological data in a computerized geo-based grid system, opens the way for the use of highly descriptive and accurate plant simulation models. Such models not only supply accurate yields, but also provide plant descriptive information that can be verified with field or remote sensing techniques.

The CROPCAST System is well suited for estimating wheat production in Afghanistan for the following reasons:

1. It provides a detailed diagnosis of the specific meteorological condition in the wheat growing zones through the application of an integrated use of the combination of meteorological satellite/radar data and ground observations.

2. It maintains an internal clock which defines the growth state (GS) of the wheat plant measured from planting.

usage by province. Where applicable, expert opinion was again used to account for current changes in fertilizer usage not reflected in the data.

The crop reduction factors were employed to account for current stresses imposed on the growing crop, (i.e. excessive heat, drought, insect/microbiotic pests, labor demographics, etc.). Determination of these factors was carried out according to the basic CROPCAST modeling approach. The provincial base yield estimates are shown in Table 3-1.

### 3.2 Monitoring of Afghanistan Wheat Yields

A major benefit of the CROPCAST system is its ability to monitor yields or yield changes on a daily basis at the 12.5 x 12.5 km cell level. The process for providing these estimates involves six steps:

**Step 1:** Two or more NOAA polar orbiting satellite data sets were obtained daily in near real-time through the CROPCAST on-line connection to the satellite image data bank. A sample of this type of data is presented in Figure 3-1.

**Step 2:** The satellite data were then analyzed to obtain areas of cloudiness and precipitation.

**Step 3:** The analyzed satellite images were manually digitized into the CROPCAST system to provide inputs into the modeling system described in Section 1.0. An example of a model output for seven-day precipitation is shown in Figure 3-2.

**Step 4:** The CROPCAST yield estimation model was run to assess changes in soil moisture, crop condition, and growth stage.

**Step 5:** The loss function was applied to provide yield estimates at the appropriate level.

**Step 6:** Aggregate the yield assessments to the district and/or province level. Each 12.5 x 12.5 km level cell is assigned to a district and province based upon the centroid of the cell. The area-weighted yield estimates were then summarized to the province level.

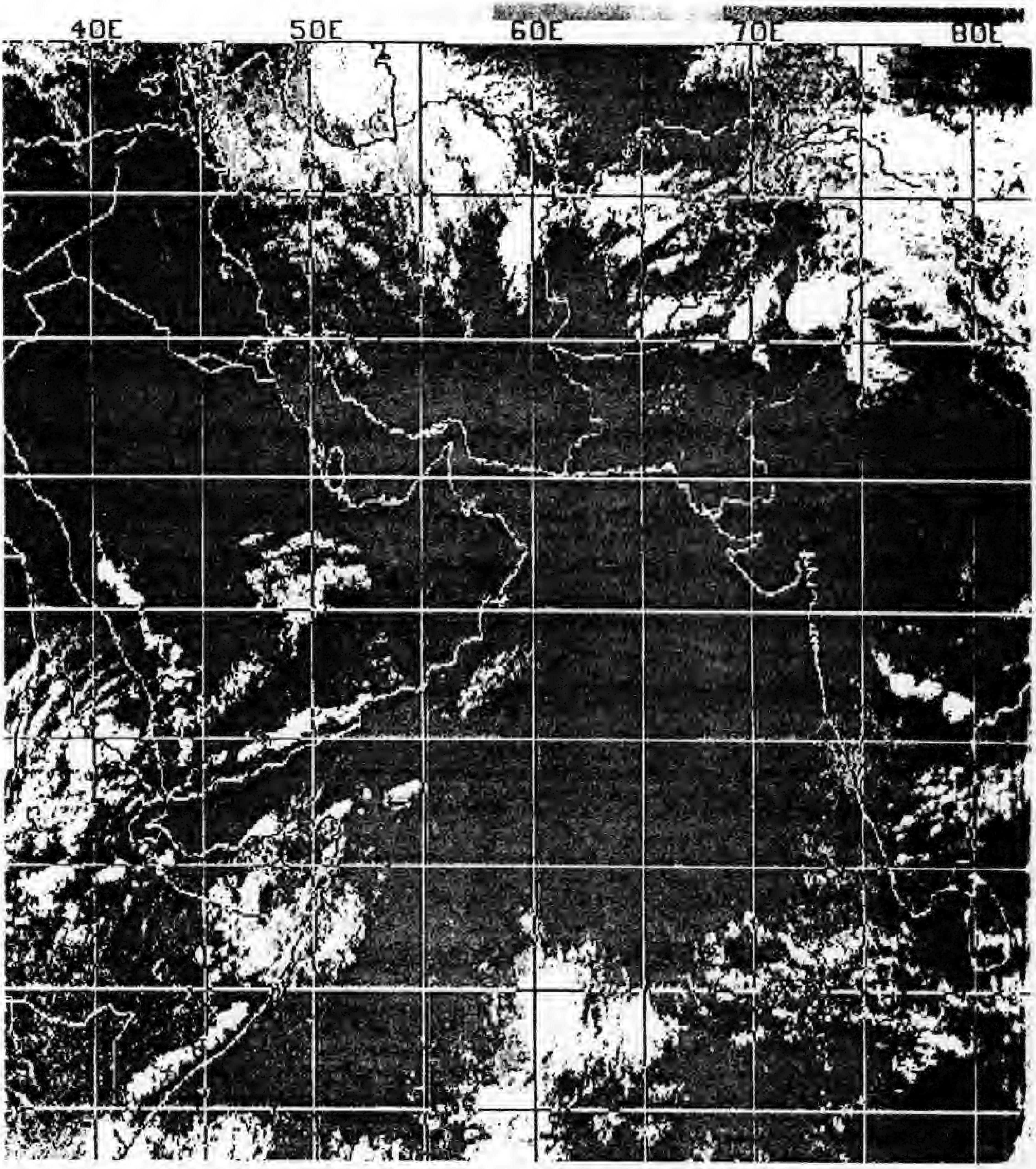


Figure 3-1
Sample of NOAA Polar Orbiting Satellite Imagery
used in monitoring environmental conditions in Afghanistan

CROPCAST
1990 BASE YIELD CALCULATIONS

| PROVINCE | NATIONAL BASE YIELD (KG/HA) | PROVINCE COEFFICIENT | PROVINCE BASE YIELD (KG/HA) | IRRIGATED BASE YIELD (KG/HA) | RAINFED BASE YIELD (KG/HA) |
|---|---|---|---|---|---|
| WEST REGION | | | | | |
| Herat | 1250 | 1.30 | 1625 | 1670 | 835 |
| NORTHWEST REGION | | | | | |
| Badghis | 1250 | 0.75 | 940 | 1720 | 860 |
| Farayab | 1250 | 0.70 | 875 | 1620 | 810 |
| Jowzjan | 1250 | 0.70 | 875 | 1460 | 730 |
| Balkh | 1250 | 0.90 | 1125 | 1740 | 870 |
| Samangan | 1250 | 1.05 | 1310 | 1570 | 785 |
| NORTH REGION | | | | | |
| Baghlan | 1250 | 1.15 | 1440 | 1560 | 780 |
| Kunduz | 1250 | 1.15 | 1440 | 1620 | 810 |
| Takhar | 1250 | 1.00 | 1250 | 1630 | 815 |
| NORTHEAST | | | | | |
| Badakhshan | 1250 | 0.75 | 940 | 1330 | 665 |
| CENTRAL | | | | | |
| Bamyan | 1250 | 0.90 | 1125 | 1240 | 620 |
| Ghor | 1250 | 0.85 | 1060 | 1280 | 640 |
| EAST CENTRAL | | | | | |
| Parwan | 1250 | 1.25 | 1560 | 1610 | 805 |
| Kapisa | 1250 | 1.05 | 1310 | 1310 | 655 |
| Laghman | 1250 | 1.05 | 1310 | 1340 | 670 |
| Kabul | 1250 | 1.05 | 1310 | 1350 | 675 |
| Wardak | 1250 | 1.05 | 1310 | 1310 | 655 |
| Lowgar | 1250 | 1.10 | 1375 | 1430 | 715 |
| SOUTH CENTRAL | | | | | |
| Uruzghan | 1250 | 0.90 | 1125 | 1210 | 605 |
| Ghazni | 1250 | 1.15 | 1440 | 1480 | 740 |
| Zabul | 1250 | 1.20 | 1500 | 1580 | 790 |
| EAST | | | | | |
| Ninghrehar | 1250 | 1.00 | 1250 | 1340 | 670 |
| Kunar | 1250 | 1.10 | 1375 | 1500 | 750 |
| Paktia/Paktika | 1250 | 1.10 | 1375 | 1440 | 720 |
| SOUTHWEST | | | | | |
| Kandahar | 1250 | 1.30 | 1625 | 1650 | 825 |
| Helmand | 1250 | 1.25 | 1563 | 1710 | 855 |
| Farah | 1250 | 1.00 | 1250 | 1250 | 625 |
| Nimruz | 1250 | 1.00 | 1250 | 1250 | 625 |

**TABLE 3-1.** CROPCAST 1990 base yield calculations. A national base yield of 1,250 kg/ha was assumed based upon expert opinion and historical data.

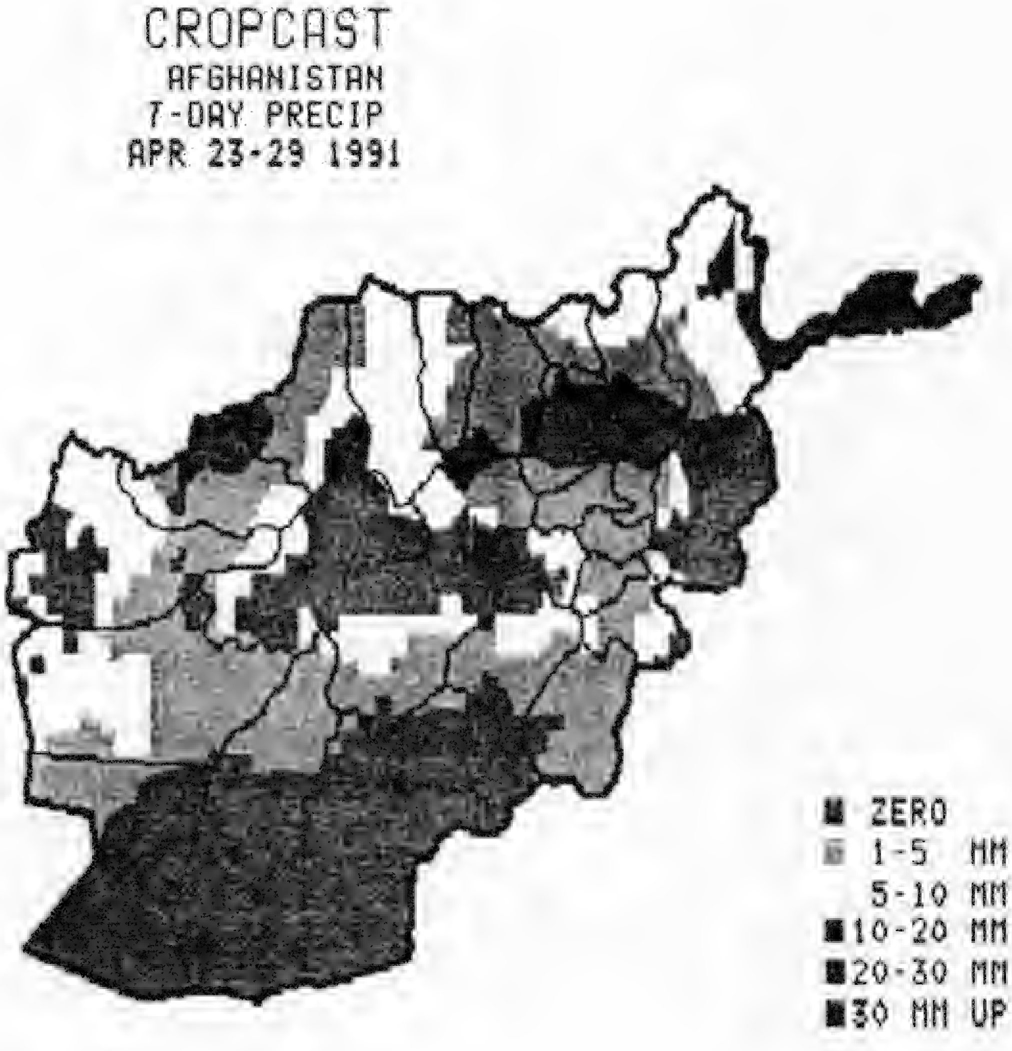


**FIGURE 3-2.** Seven-day total precipitation categories for Afghanistan for April 23-29, 1991.

### 3.3 Model Calibration

Model calibration is a necessary step for improving the wheat production monitoring process. This effort is an ongoing process involving calibration of the remotely sensed area data with ground truth data obtained either through meteorological ground station data or ground surveys. Any ground station data can be used to calibrate the weather parameters in the model using standard regression approaches which CROPCAST regularly employs. The steps in this approach are:

1. Obtain historical ground station weather data from Afghanistan and/or surrounding similar climate areas.

2. Analyze cloud cover and type over the region.

3. Statistically correlate the weather station data and the satellite parameters.

4. Update the model coefficients.

A second calibration effort for this project was to correlate ground truth survey data with the remotely sensed area data and the model yield data. The steps in this approach are:

1. Select sample sites.

2. Prepare a list of questions to be asked of local officials and/or farmers near the sample sites.

3. Collect data.

4. Statistically correlate ground data with area assessments.

5. Update known signatures for wheat.

6. Statistically correlate yields in model with yields in ground survey.

7. Update model yield coefficients.

During the early spring of 1991, ground truth sites were selected from Landsat imagery, and a survey form was prepared for DAI to conduct ground truthing in the summer of 1991. The survey form is presented in Appendix B.

### 3.4 Summary of 1990 Wheat Production Estimates

For the purposes of aggregation, a regional production summation was devised for Afghanistan. These regions are shown in Figure 3-3. An overview of the 1990 growing conditions for each region is presented below. The regional production estimates are detailed in Table 3-2.

**Region 1 (West):** The Harirud River valley was diagnosed as having a mostly near-normal growing season in 1990. Total Herat production was estimated at 209,000 metric tons.

**Region 2 (Northwest):** This region was estimated to have a 20 to 30 percent below-normal production year in 1990 due to dryness in the spring which impacted the rainfed crop, and also due to spotty but intense sunn pest problems as described in Section 2.0. Total 1990 regional production was estimated at 755,000 metric tons.

**Region 3 (North):** The northern region of Afghanistan experienced below-normal production in the western one-third of the region, with improving conditions eastward so that eastern parts of the region were diagnosed as having above-normal production. Total 1990 production for the north region was forecast at 477,000 metric tons.

**Region 4 (Northeast):** This minor producing area which is mostly comprised of small fields in mountainous areas was diagnosed as having a total wheat production of 28,000 metric tons in 1990.

**Region 5 (Central):** This region also experienced a good production year in 1990 as irrigation water was mostly adequate in the region. Total regional production was forecast at 167,000 metric tons.

**Region 6 (East Central):** Intermountain valley water supplies were good in this region in 1990, resulting in above-normal yields and

AFGHANISTAN REGIONS

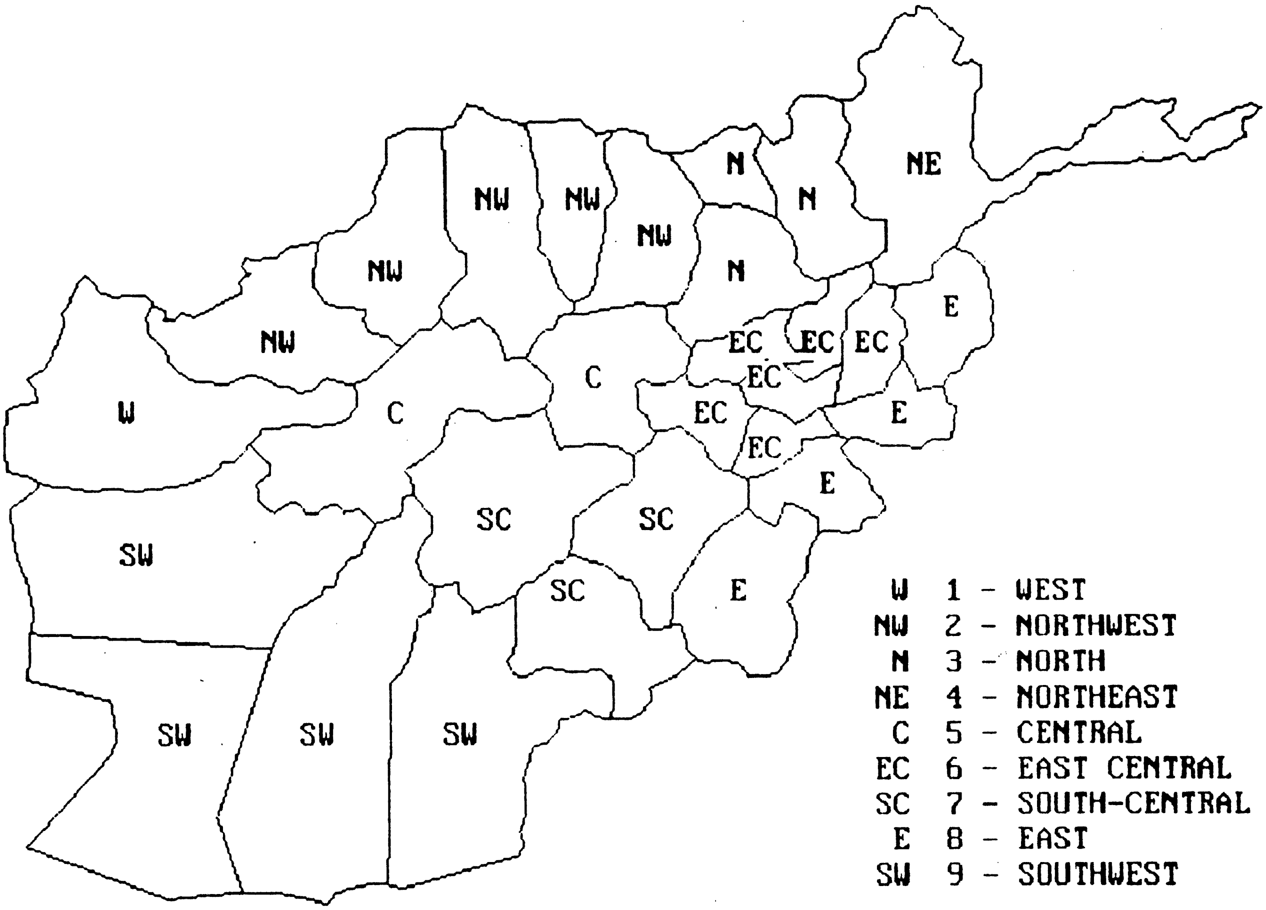


FIGURE 3-3. CROPCAST™ regional delineations.

CROPCAST
MAY 1, 1991
COMPONENT PRODUCTION

| PROVINCE | FORECAST IRRIGATED AREA (HECTARE) | FORECAST IRRIGATED YIELD (KG/HA) | FORECAST IRRIGATED PRODUCTION (MT) | FORECAST RAINFED AREA (HECTARE) | FORECAST RAINFED YIELD (KG/HA) | FORECAST RAINFED PRODUCTION (MT) |
|---|---|---|---|---|---|---|
| WEST REGION | | | | | | |
| Herat | 126,070 | 1587 | 200,010 | 12,910 | 668 | 8,624 |
| NORTHWEST REGION | | | | | | |
| Badghis | 39,180 | 1462 | 57,281 | 199,870 | 516 | 103,133 |
| Farayab | 77,830 | 1296 | 100,868 | 159,280 | 405 | 64,508 |
| Jowzjan | 71,980 | 1241 | 89,327 | 251,550 | 438 | 110,179 |
| Balkh | 58,810 | 1653 | 97,213 | 120,480 | 783 | 94,336 |
| Samangan | 15,460 | 1570 | 24,272 | 17,680 | 785 | 13,879 |
| NORTH REGION | | | | | | |
| Baghlan | 58,330 | 1560 | 90,995 | 10,900 | 780 | 8,502 |
| Kunduz | 122,220 | 1620 | 197,996 | 19,960 | 810 | 16,168 |
| Takhar | 47,000 | 1712 | 80,441 | 96,310 | 856 | 82,417 |
| NORTHEAST | | | | | | |
| Badakhshan | 11,440 | 1463 | 16,732 | 14,830 | 731 | 10,845 |
| CENTRAL | | | | | | |
| Bamyan | 21,660 | 1302 | 28,201 | 0 | 682 | 0 |
| Ghor | 89,070 | 1280 | 114,010 | 37,270 | 672 | 25,045 |
| EAST CENTRAL | | | | | | |
| Parwan | 11,560 | 1610 | 18,612 | 0 | 765 | 0 |
| Kapisa | 15,130 | 1310 | 19,820 | 0 | 655 | 0 |
| Laghman | 18,310 | 1407 | 25,762 | 340 | 737 | 251 |
| Kabul | 31,610 | 1350 | 42,674 | 240 | 675 | 162 |
| Wardak | 36,410 | 1310 | 47,697 | 90 | 655 | 59 |
| Lowgar | 3,830 | 1430 | 5,477 | 880 | 715 | 629 |
| SOUTH CENTRAL | | | | | | |
| Uruzghan | 51,290 | 1210 | 62,061 | 1,120 | 605 | 678 |
| Ghazni | 161,200 | 1554 | 250,505 | 4,440 | 814 | 3,614 |
| Zabul | 32,020 | 1659 | 53,121 | 6,570 | 869 | 5,709 |
| EAST | | | | | | |
| Ninghrehar | 37,230 | 1407 | 52,383 | 0 | 737 | 0 |
| Kunar | 13,680 | 1650 | 22,572 | 130 | 900 | 117 |
| Paktia/Paktika | 55,450 | 1512 | 83,840 | 1,820 | 792 | 1,441 |
| SOUTHWEST | | | | | | |
| Kandahar | 106,310 | 1815 | 192,953 | 25,520 | 990 | 25,265 |
| Helmand | 69,260 | 1796 | 124,356 | 0 | 941 | 0 |
| Farah | 76,480 | 1250 | 95,600 | 0 | 625 | 0 |
| Nimruz | 23,430 | 1313 | 30,752 | 0 | 688 | 0 |
| TOTAL | 1,482,250 | 1501 | 2,225,530 | 982,190 | 586 | 575,561 |

**TABLE 3-2.** Provincial production estimates for irrigated and rainfed wheat for 1990.

production. Regional production was forecast at 161,000 metric tons.

**Region 7 (South Central):** Irrigation water supplies in this region were adequate with the main production determinant being the health of poorly-maintained irrigation systems. Total regional production was estimated at 376,000 metric tons.

**Region 8 (East):** Yields and production were above normal in this region during 1990 as snowmelt produced sufficient irrigation supplies for the entire year. The East region production estimate was 160,000 metric tons.

**Region 9 (Southwest):** This region, which is dominated by irrigation system agriculture along the major river valleys showed good production outturn in 1990 as the water supplies were adequate during the growing season. Total 1990 regional production was estimated at 469,000 metric tons.

Country level production for 1990 was estimated at 2.801 million metric tons (mmt), consisting of 2.226 mmt of irrigated production, and 0.576 mmt of rainfed production. Total area in wheat was 2.46 million hectares (mha), and the average national yield was forecast at 1,137 kg/ha. A national production summary is shown in Table 3-3.

## 3.5 Preliminary 1991 Wheat Conditions

Near normal rainfall typified the fall planting season across the northern areas of Afghanistan from Herat eastward to Kunduz and Baghlan. Precipitation was only slightly less than normal in the mountains. The areas that were drier than normal were in the south and east from Helmand to Kabul and Ningrehar.

During the early winter in late November and December precipitation gradually increased to normal in the mountains but the southern areas remained drier than normal.

CROPCAST
MAY 1, 1991 FINAL
1990 AFGHAN WHEAT ESTIMATE

| PROVINCE | TOTAL AREA (HECTARE) | YIELD (KG/HA) | TOTAL PRODUCTION (METRIC TONS) |
|---|---|---|---|
| WEST REGION - 1 | | | |
| Herat | 138,980 | 1501 | 208,634 |
| NORTHWEST REGION - 2 | | | |
| Badghis | 239,050 | 671 | 160,414 |
| Farayab | 237,110 | 697 | 165,376 |
| Jowzjan | 323,530 | 617 | 199,506 |
| Balkh | 179,290 | 1068 | 191,549 |
| Samangan | 33,140 | 1151 | 38,151 |
| NORTH REGION - 3 | | | |
| Baghlan | 69,230 | 1437 | 99,497 |
| Kunduz | 142,180 | 1506 | 214,164 |
| Takhar | 143,310 | 1136 | 162,858 |
| NORTHEAST - 4 | | | |
| Badakhshan | 26,270 | 1050 | 27,578 |
| CENTRAL - 5 | | | |
| Bamyan | 21,660 | 1302 | 28,201 |
| Ghor | 126,340 | 1101 | 139,055 |
| EAST CENTRAL - 6 | | | |
| Parwan | 11,560 | 1610 | 18,612 |
| Kapisa | 15,130 | 1310 | 19,820 |
| Laghman | 18,650 | 1395 | 26,013 |
| Kabul | 31,850 | 1345 | 42,836 |
| Wardak | 36,500 | 1308 | 47,756 |
| Lowgar | 4,710 | 1296 | 6,106 |
| SOUTH CENTRAL - 7 | | | |
| Uruzghan | 52,410 | 1197 | 62,739 |
| Ghazni | 165,640 | 1534 | 254,119 |
| Zabul | 38,590 | 1525 | 58,831 |
| EAST - 8 | | | |
| Ninghrehar | 37,230 | 1407 | 52,383 |
| Kunar | 13,810 | 1643 | 22,689 |
| Paktia/Paktika | 57,270 | 1489 | 85,282 |
| SOUTHWEST - 9 | | | |
| Kandahar | 131,830 | 1655 | 218,217 |
| Helmand | 69,260 | 1796 | 124,356 |
| Farah | 76,480 | 1250 | 95,600 |
| Nimruz | 23,430 | 1313 | 30,752 |
| NATIONAL TOTAL | 2,464,440 | 1137 | 2,801,092 |

**TABLE 3-3.** National provincial summary of Afghan wheat production for 1990.

3. It contains a subsystem which integrates crop condition assessments for evaluating yield factors, such as pests, technological changes, etc., not evaluated in the physiological model process.

The following are the key functional descriptions for the Afghan wheat yield process.

### 1.2.1 Potential Evapotranspiration (ETP)

There are radiative and advective components of ETP.

$$ETP_{RAD} = K_1 R_{SOLAR}$$
$$ETP_{ADV} = -K_1 R_{LW} + K_2 * f(W) * (e_s - e_a)$$

where:

$K_1, K_2$ = constants
$R_{SOLAR}$ = the solar radiation reaching the surface
$R_{LW}$ = the long wave outgoing radiation
$f(W)$ = a function of the total wind movement
$e_s$ = the saturation vapor pressure
$e_a$ = the actual vapor pressure

By defining these particular components of ETP, it is possible to define the net ETP acting on the crop as

$$ETP = ET_{RAD} * (1 - a) + ETP_{ADV}$$

where:

$a$ = the albedo of the field.

### 1.2.2 Biometeorological Time Clock

The 12.5 km grid spacing is the basis for the Afghan agronomic analysis. Sixteen 12.5 x 12.5 km cells surround each of the standard 48 km mesh intersections. They share the meteorology in common but can each have their own Biometeorological Time Clock (Growth Stage Calculations):

$$PTU = L_{DAY} * T + f(ST, CPTU)$$

Where:

$L_{DAY}$ = the number of hours of daylight
$T$ = the mean temperature for the day
$f(ST, CPTU)$ is a modifier based on stress and current growth stage.

A major change occurred in weather patterns affecting the Afghanistan wheat areas during mid-January. Several storm systems brought heavy precipitation to the Afghanistan mountain regions during the April to June period. The mountain snowpack is as much as fifty percent above normal. The CROPCAST snowpack analysis as of March 11, 1991, compared to normal, is shown in Figure 3-4. This will lead to two events as the spring unfolds. First, there will be some flooding problems in valleys prone to high water events. Second, the heavy snowpack will result in abundant irrigation supplies which will translate into increased yields once the threat of flooding subsides.

The actual extent of flooding problems will be a function of rainfall during the spring and the rapidity of the spring warming which will impact the snowmelt and subsequent runoff.

The CROPCAST early assessment of 1991 Afghanistan wheat production assumes improved yields over 1999, especially in the north. **Our early assessment of 1991 Afghanistan wheat production is 3.05 mmt.**

### 3.6 Demonstration Program on GIS Integration

A great deal of varied information about Afghan agriculture, geography, and climatology was collected as part of the first year Afghan CROPCAST program. It was realized early in the program that this information had other utilities not directly related to wheat production forecasting. Consequently, in the spring of 1991, this information was organized and integrated into a set of demonstration Geographic Information System (GIS) data layers for presentation of the utilities of GIS technology in agricultural and development planning.

The data layers created included the following:

Soils
Elevation

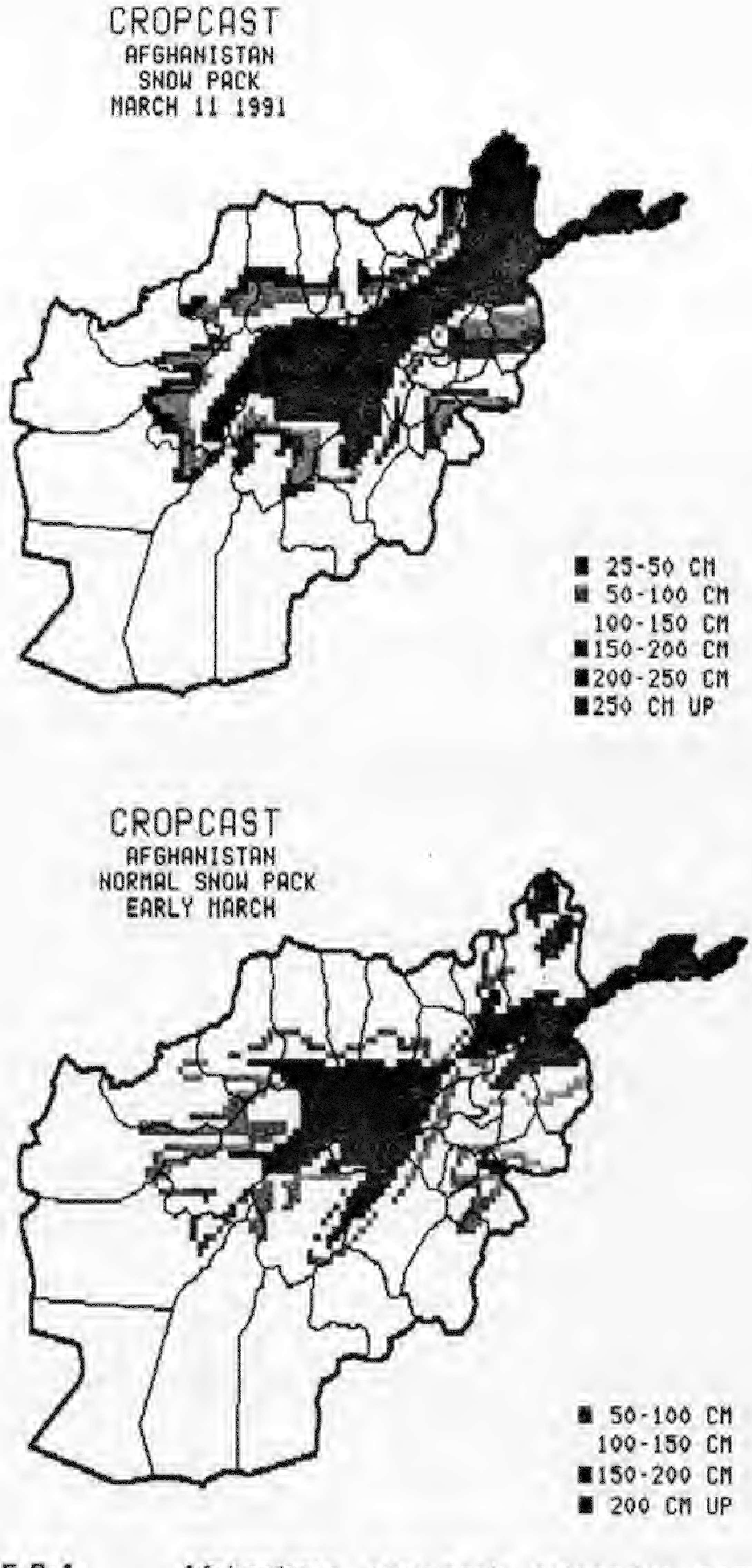


**FIGURE 3-4.** Afghanistan snowpack categories compared to normal for March 11, 1991.

Slope and aspect
Stream network
Irrigation network
Cultivation area
Wheat area and yield
Pestilence area extent
Rainfall
Snowpack extent and depth
Temperature (average and diurnal variation)
Political boundaries

These sample data layers were either nationwide, compiled from generalized sources, or were limited to small geographic areas for the purposes of demonstration. Once these layers were created, it became possible to begin to extract models from the GIS based upon various geographic parameters. For example, the elevation, slope, soil, and minimum temperature and maximum temperature variation requirements for horticultural cash crops, such as pomegranate, are well-documented. Using these parameters, the geographic extent of the areas in Afghanistan which meet all the appropriate criteria for successful growth of pomegranate were identified in the GIS, and displayed in map format. This allows donors to maximize their investment effectiveness by applying their resources to those geographic areas which have the best potential for success of the given crop.

This concept can be further refined with the addition of other data layers. for example, the exploitation potential of a particular crop might be limited by distance to market or access to transportation. Data layers depicting the location of major market centers and a passable road network could be added to the GIS, allowing the limitations of these parameters to be included in the geographic analysis, yielding a more limited, yet refined, potential crop growth area. The potential of GIS in development is limited only by the type and quality of data which is entered.

The above data layers were manipulated as described above to yield GIS demonstration models which included the following:

**Irrigation Water Availability** based upon rainfall, snowpack extent and depth, and stream network.

**Irrigation Area Temporal Change** based upon cultivation area and irrigation network.

**Crop Suitability** based upon rainfall, temperature, irrigation water availability, soils, elevation, and slope and aspect.

**Rotation Crop Suitability** based upon soils, elevation, rainfall, temperature, snowpack extent and depth, and wheat area and yield.

**Insect Damage Assessment** based upon pestilence area and cultivation area

**Potential Yield Change** based upon wheat yield, rainfall, snowpack extent and depth, and pestilence area.

**Potential Production** based upon cultivation area, wheat area and yield, rainfall, snowpack extent and depth, and pestilence area.

The above demonstration models were prepared and graphically portrayed, and presented to representatives of USAID and other agencies on March 29, 1991, to demonstrate the various applications of the CROPCAST and GIS development during year one of the project.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

The following were key findings from the Afghan CROPCAST first year study:

1. An estimated 1.48 million ha were in irrigated (winter) wheat in the growing year 1989-1990. Regional and provincial total areas for irrigated wheat are shown in Table 2-2A.

2. An estimated 0.98 million ha were in rainfed (spring) wheat in the growing year 1990. Regional and provincial totals are shown in Table 2-2B.

3. An estimated total of 1.65 million ha of active irrigated agriculture is forecast for spring 1990 from visual analysis. This number includes all areas classified as active agriculture (A1), and inactive irrigated land and non-cultivated inclusions which were not separable from active irrigated agriculture at the mapping scale.

4. An estimated total of 2.21 million ha of rainfed agricultural land is forecast for spring 1990 from visual analysis. This number includes all areas classified as active rainfed agriculture (A2), and inactive rainfed land and non-cultivated inclusions which were not separable from active rainfed agriculture at the mapping scale.

5. Total wheat production estimated for 1990 was 2.801 mmt, consisting of 2.226 mmt of irrigated wheat, and 0.576 mmt of rainfed wheat.

6. The early assessment of 1991 wheat production indicates production will total 3.05 mmt.

7. There was a significant amount of idle (inactive) agricultural land detected on visual analysis.

8. Phenomena impacting wheat area (pestilence, irrigation problems, etc.) reported by expert opinion were generally confirmed by visual image analysis. However, the case for unavailability of irrigation water was, on the whole, overstated by expert opinion.

9. The Landsat Thematic Mapper (TM) sensor is exceedingly useful in agricultural detection in Afghanistan, due to its combination of moderate spatial resolution (30 m) and superior spectral resolution (six narrow reflective bands).

10. The Landsat Multi-Spectral Scanner (MSS) sensor is capable of satisfactory agricultural detection in areas of large fields; i.e., primarily in lowland valleys and open plains. However, its limited spatial (80 m) and spectral (four wide reflective bands) resolution make it less useful in mountainous areas, or where there are small fields intermixed with non-agricultural lands.

11. The SPOT Multi-Spectral (XS) sensor provides superior (20 m) spatial resolution, but is limited in its spectral resolution (three narrow reflective bands). Additionally, the area coverage of a single SPOT scene is much smaller than Landsat, resulting in a prohibitive

cost for data acquisition and processing for a nationwide inventory or survey program. However, SPOT-XS imagery could be highly useful in a limited role as either an interpreter training tool, or as a means of obtaining the closest approximation of ground truth possible in Afghanistan at the present time, given the political climate. SPOT-XS data could also be used to measure the statistical accuracy of Landsat TM analysis in areas of small agricultural field size.

12. A modeling system was implemented for yield assessments that successfully assessed conditions at the 12.5 x 12.5 km grid size.

13. A snowpack model was implemented for evaluating winter snowpack and subsequent springtime water availability.

14. A calibration program has been activated for reducing the errors in production estimates over Afghanistan for 1992 and 1993.

15. The CROPCAST system is an excellent data resource for crop suitability and other planning assessments.

Key recommendations derived from the research and operation of the Afghan CROPCAST program include the following:

1. A nationwide inventory of agricultural land using Landsat TM (possibly combined with SPOT-XS imagery for certain areas) should be conducted to provide a completely objective baseline of agricultural area for future use.

2. Subsequent wheat analyses (after a nationwide inventory) can be limited to the major production regions in order to minimize image acquisition, processing, and analysis costs (Helmand, Ghazni, Qandahar, Helmand, Jowzjan/Farayab, and Kunduz/Baghlan).

3. If access to sufficient ground truth becomes available in the future, digital classification of wheat area should be attempted.

4. Results of future studies should be incorporated into a nationwide resource Geographic Information System (GIS) database to permit expedited data analysis, modeling, and change detection.

5. Compilation of statistics should be derived at the district level and then aggregated to the province level for better definition of local wheat surpluses and shortfalls.

6. The wheat production data should be integrated with demand side data for a better definition of local and regional shortfalls and transportation potential.

7. A ground-truthing program should be established for aiding the calibration efforts of this project. Such a program has been instituted by DAI which will begin to produce positive results on accuracy during 1992.

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### 1.2.3 Soil Moisture Budget

$$ET_j = K_j\, C_j\, Z_j\, ETP * e^{-W(ETP - \overline{ETP})}$$

Where:

| | | |
|---|---|---|
| $K_j$ | = | the coefficient of water extractability for zone j |
| $C_j$ | = | the ratio of available soil moisture in zone j to its capacity |
| $Z_j$ | = | a soil dry down curve coefficient, a function of soil texture and current moisture content |
| ETP | = | the current day's ETP |
| W | = | is an adjustment function describing the acclimatization of the plant to the current ETP level |
| $\overline{ETP}$ | = | the average ETP over the past several days. |

Daily soil moisture values are determined by subtracting the $ET_j$ from each zone. Precipitation, if any, is input from the top layer down, filling each layer in turn until it has all been used. When daily rainfall is excessive a portion of it is assumed lost to runoff, calculated as a function of the rain amount and the wetness of the uppermost soil zone. In poorly drained locations some of the runoff is retained as surface water. The initial soils information for Afghanistan was derived from expert opinion and an analysis of historical information.

### 1.2.4 Stress and Yield Loss

The stress experienced on day i is given by:

$$ST_i = 1.0 - C_1\,(ETP_{BASE} - ETP_i) - C_2 * \ln(ET_i/ETP_i)$$

Where:

$ETP_{BASE}$ represents a climatological upper limit on ETP and $C_1$ and $C_2$ are constants.

The yield loss (in percent) on day i is given by

$$LOSS_i = ST_i * MAXLOSS_j * (PTU_i/CPTU_j)$$

Where:

| | | |
|---|---|---|
| $MAXLOSS_j$ | = | the maximum possible loss at the current growth interval, j |
| $CPTU_j$ | = | the total growth units (photothermal units or crop degree days) in the current interval. |

The yield in a cell is given by

# APPENDIX A

# LANDSAT MULTI-SPECTRAL SCANNER (MSS) AND THEMATIC MAPPER (TM) IMAGERY

**PLATE 1.** Path 153/Row 34, Landsat MSS scene 51898-05280, Dasht-e Qal'eh, Afghanistan, acquired 12 May 89.

**PLATE 2.** Path 154/Row 35, Landsat MSS scene 52257-05621, Mazar-e Sharif, Afghanistan, acquired 06 May 90.

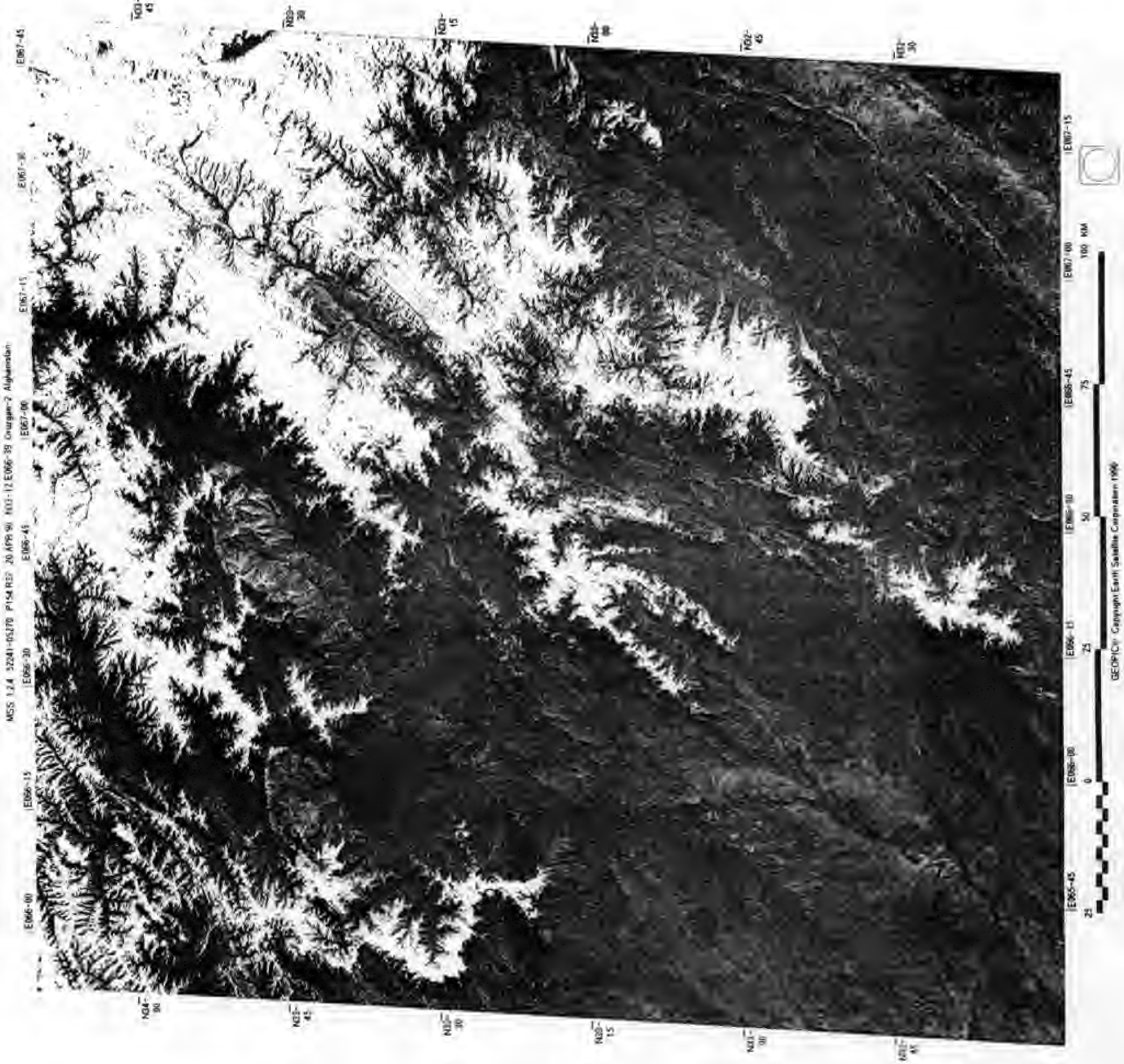


**PLATE 3.** Path 154/Row 37, Landsat MSS scene 52241-05270, Oruzgan-2, Afghanistan, acquired 20 Apr 90.

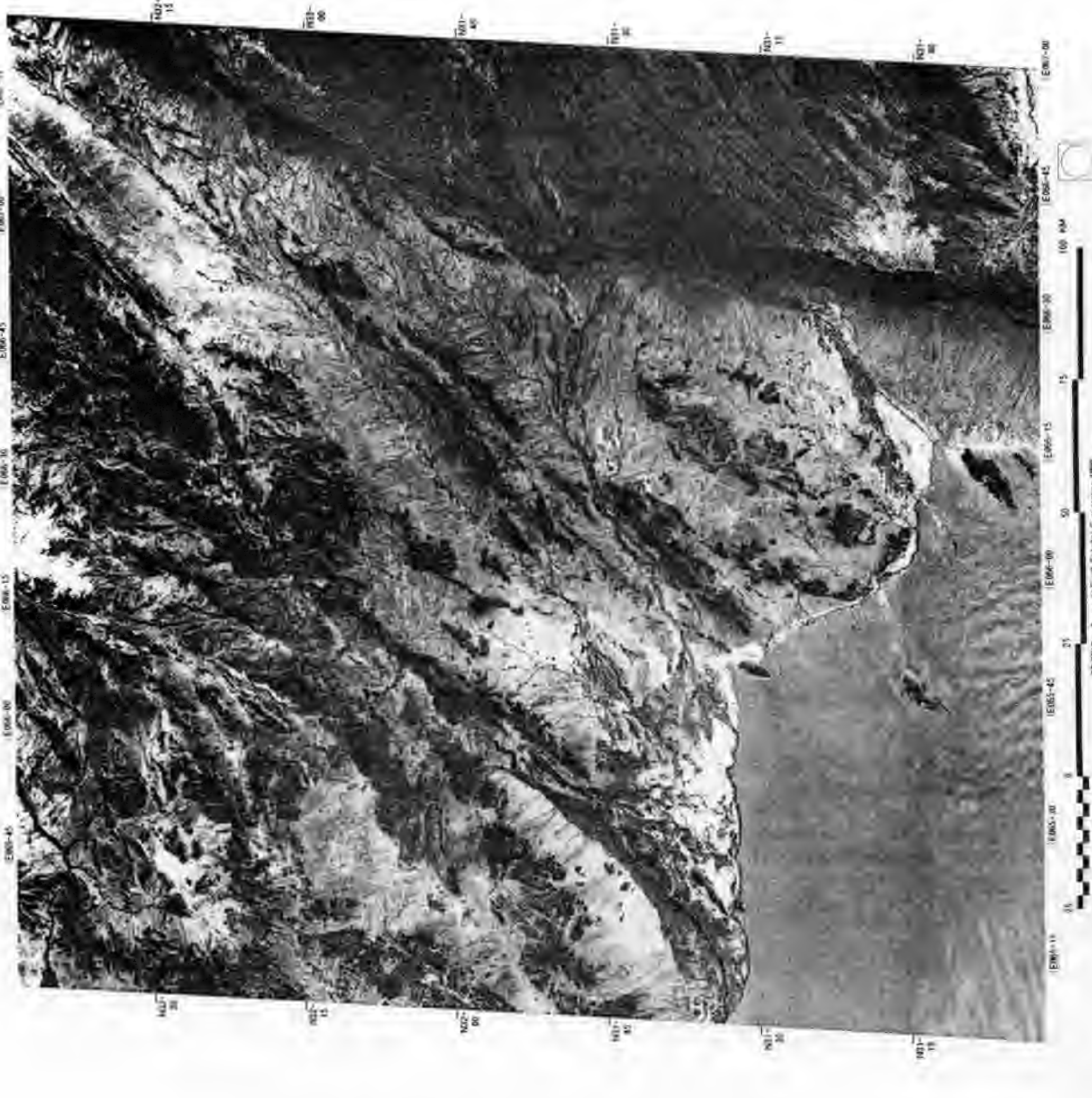


**PLATE 4.** Path 154/Row 38, Landsat MSS scene 52241-05272, Qandahar, Afghanistan, acquired 20 Apr 90.


**PLATE 5.** Path 154/Row 38, Landsat TM scene 52273-05274, Qandahar, Afghanistan, acquired 22 May 90.

**PLATE 6.** Path 155/Row 35, Landsat MSS scene 51944-05395, Sheberghan-2, Afghanistan, acquired 27 Jun 89.

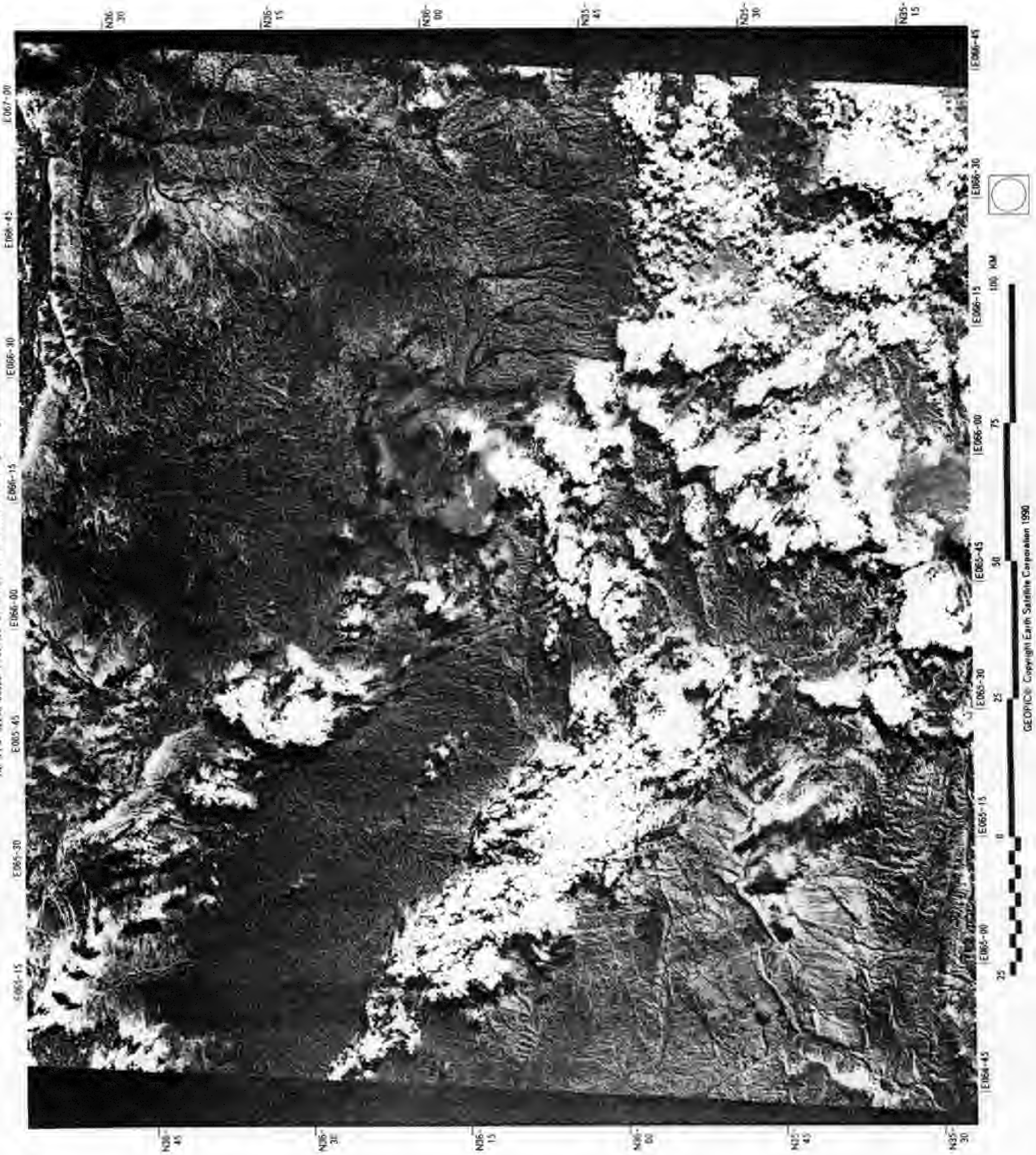


**PLATE 7.** Path 155/Row 35, Landsat TM scene 52248-05323, Sheberghan, Afghanistan, acquired 27 Apr 90.

**PLATE 8.** Path 155/Row 38, Landsat TM scene 52248-05335, Gereshk, Afghanistan, acquired 27 Apr 90.

**PLATE 9.** Path 156/Row 35, Landsat TM scene 42857-05492, Maymanah, Afghanistan, acquired 12 May 90.

$$Y_k = Y_{MAX} * (100 - \Sigma_i \, LOSS_i)/100$$

Where:

$Y_{MAX}$ = the estimated local yield attainable under ideal conditions.

The aggregated yield is given by

$$Y_{AGG} = (\Sigma_k \, Y_k * WT_k) / \quad WT_k$$

Where:

$WT_k$ is the weighing of an individual cell within the aggregated region (usually based on acreage density of the crop).

## 1.3 Application to Afghanistan

The previous parts of this Section detail the technical description of the CROPCAST model. The model application for Afghanistan required some adjustment and an on-going calibration because there was insufficient historical ground truth for a thorough scientific historical calibration process.

The CROPCAST model provides a computer-generated view of any specific crop, in this case wheat. The computer model (through it s Versatile Soil Moisture Budget and its Biometeorological Time Clock) is sensitive to the effects of water or excess temperatures on the growing crop. When moisture is short or temperatures are above a threshold the wheat plant accumulates stress and loss is observed. This loss is statistically converted to a yield estimate. Inputs to the model are obtained two to four times per day from polar orbiting imagery. Area estimates are generated through satellite image remote sensing assessment combined with historical information and expert opinion.

On-going calibration is performed as satellite data resources and ground truthing information are collected. This iterative approach results in consistently improving yield and area estimates. Details of the calibration approach for Afghanistan are presented in Section 3.3.

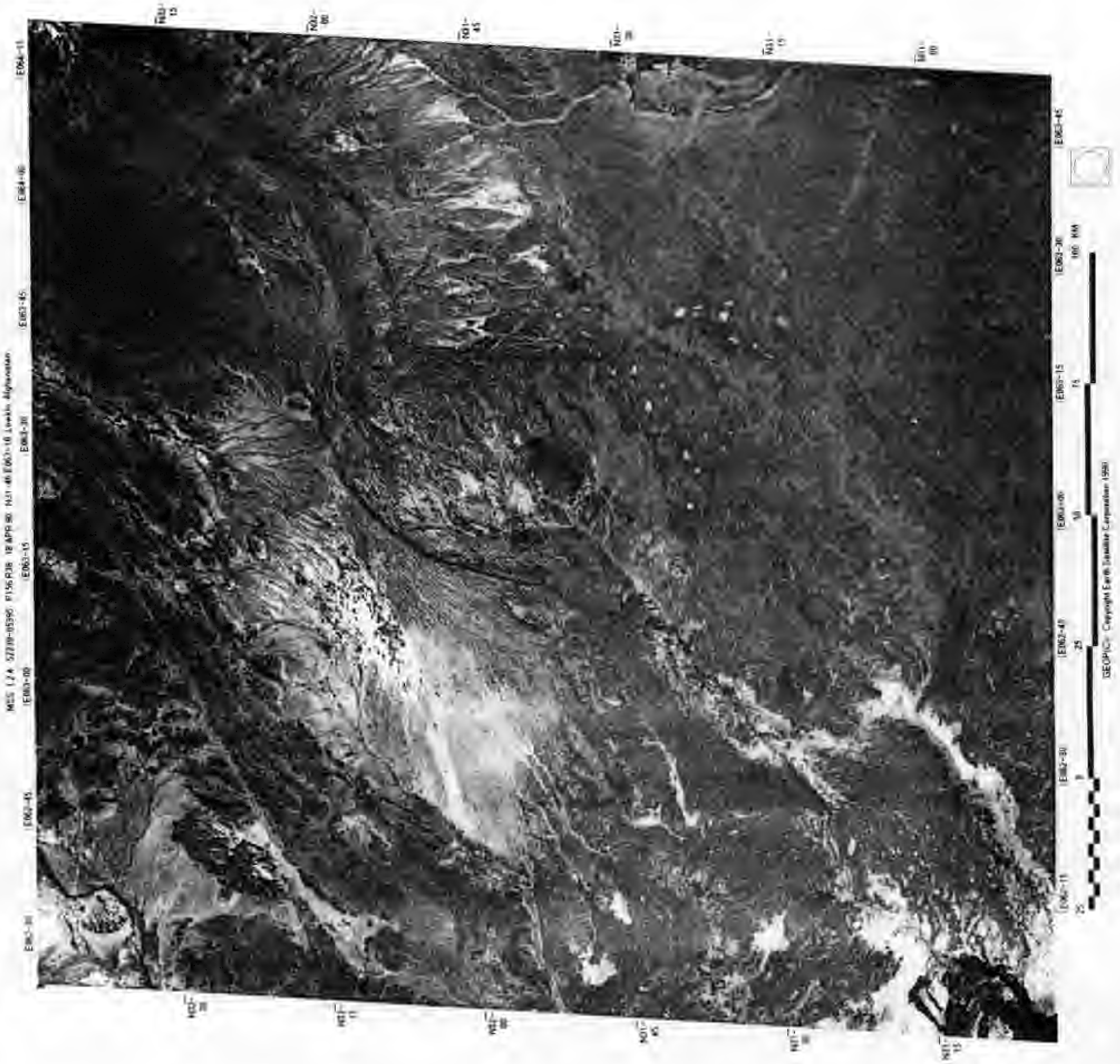


**PLATE 10.** Path 156/Row 38, Landsat MSS scene 52239-05395, Lowkhi, Afghanistan, acquired 18 Apr 90.

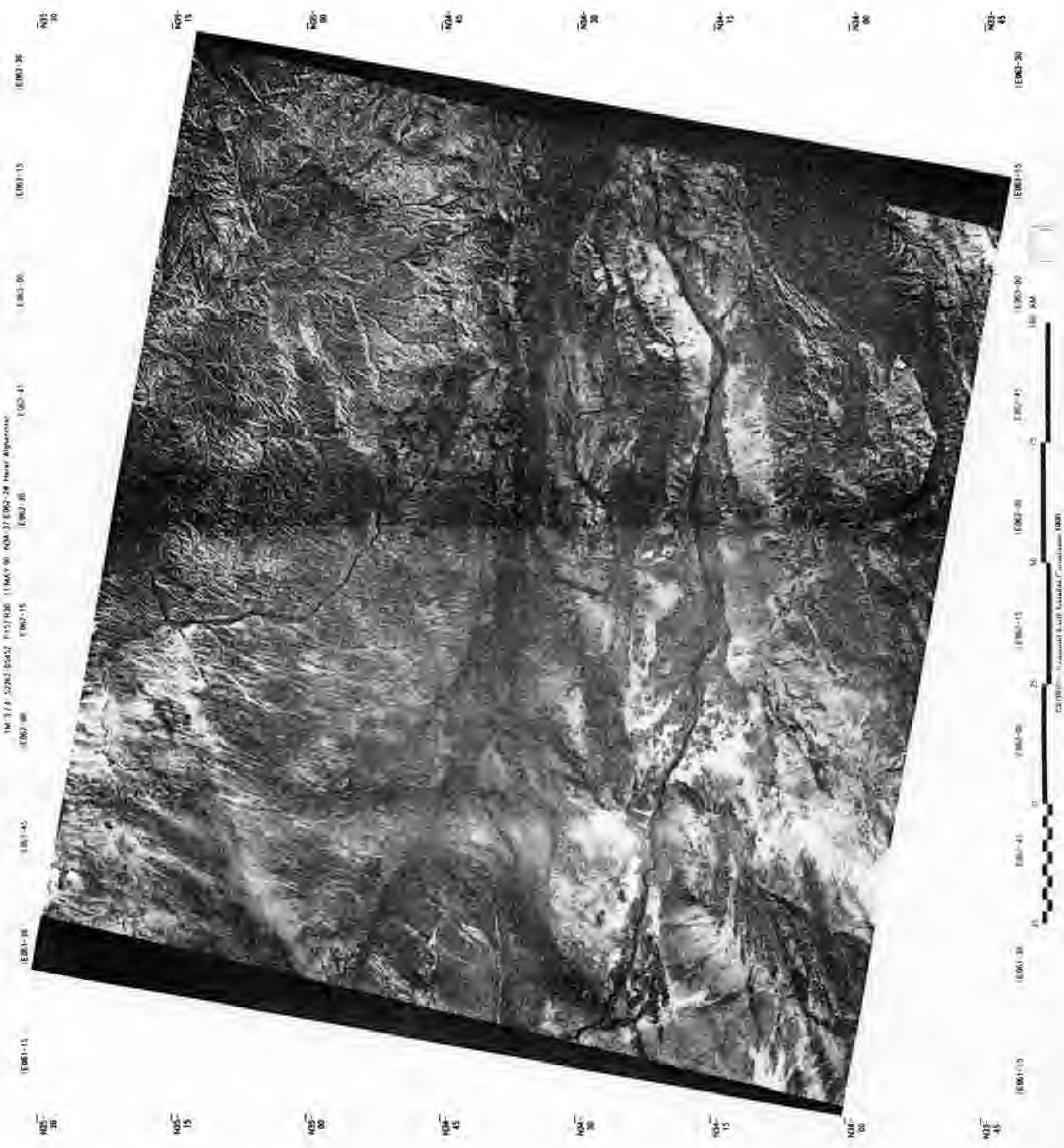


PLATE 11. Path 157/Row 36, Landsat TM scene 52262-05452, Herat, Afghanistan, acquired 11 May 90.

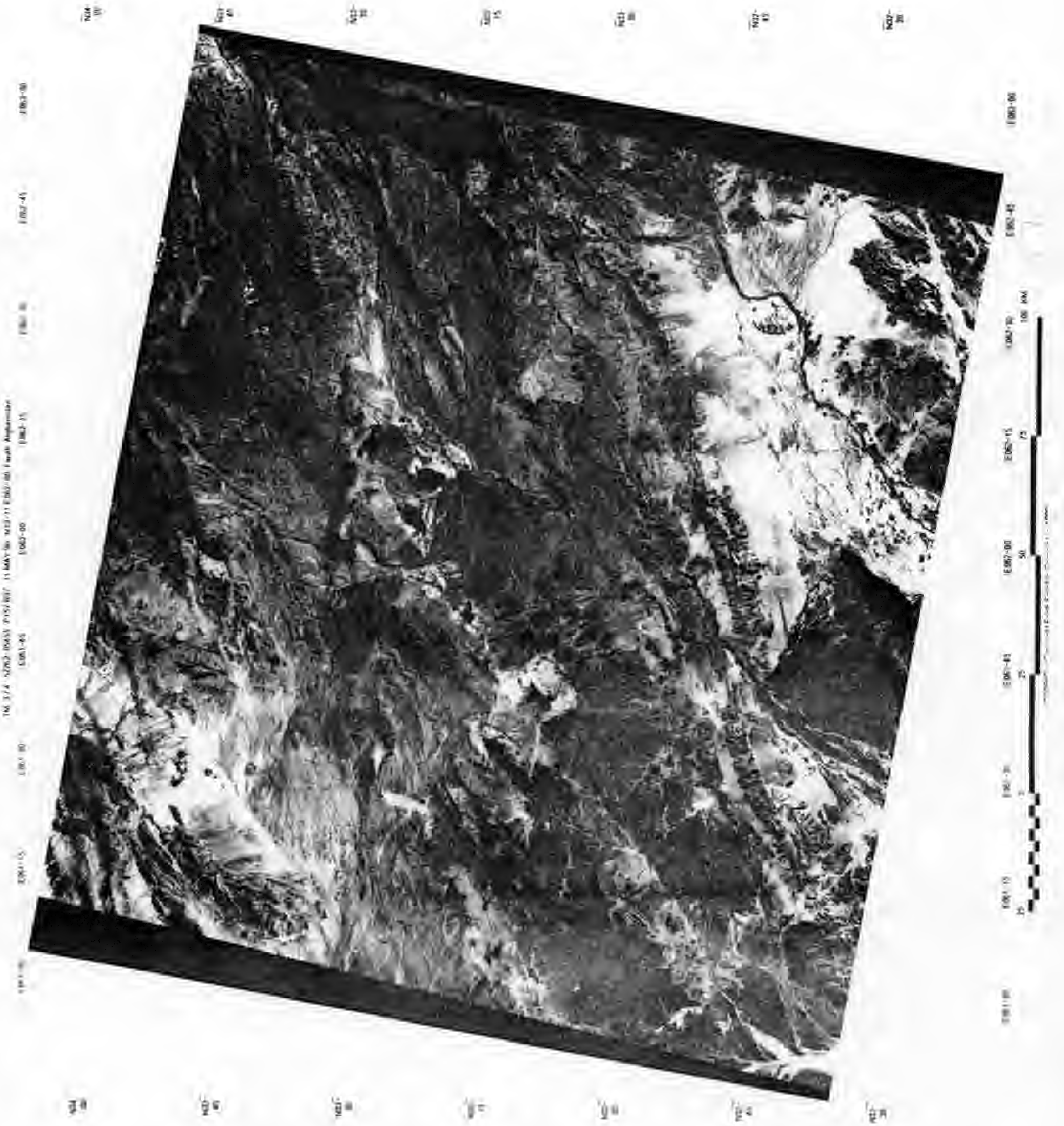


**PLATE 12.** Path 157/Row 37, Landsat TM scene 52262-05455, Farah, Afghanistan, acquired 11 May 90.

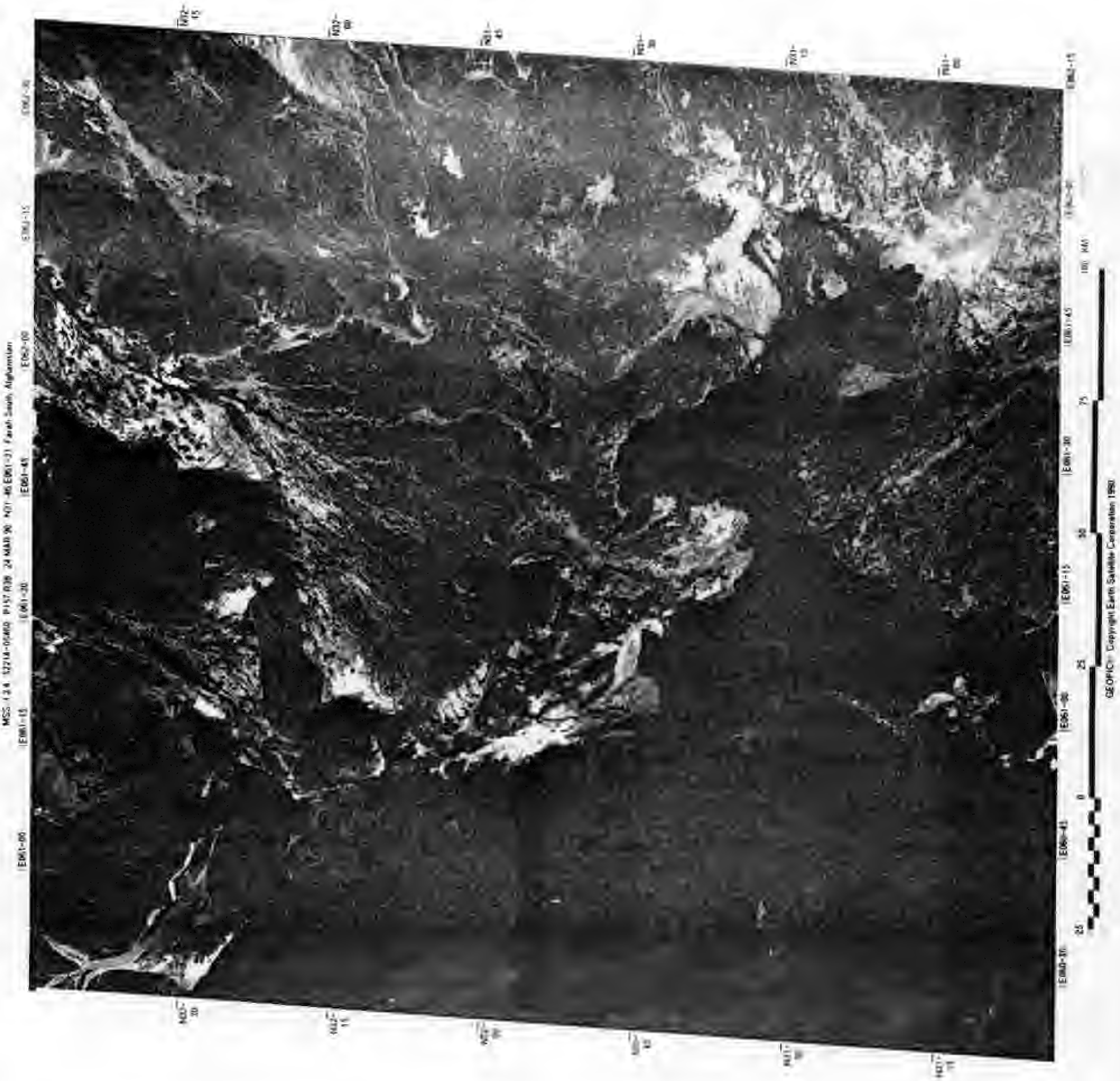


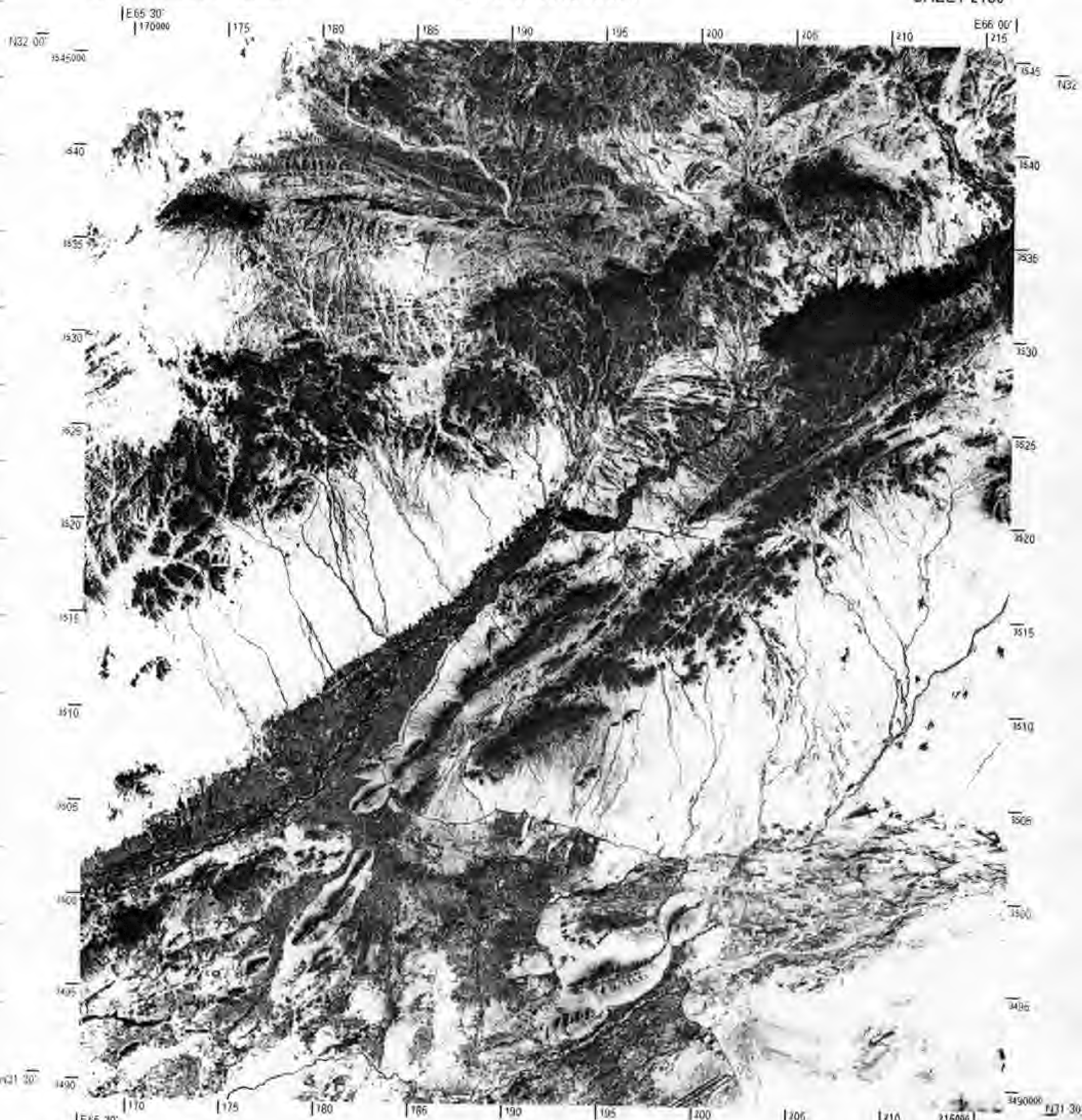
**PLATE 13.** Path 157/Row 38, Landsat MSS scene 52214-05460, Farah South, Afghanistan, acquired 24 Mar 90.

**PLATE 14.** Sample image map utilizing Landsat TM (Bands 3-7-4 in B-G-R) of Qandahar, Afghanistan. Nineteen TM image maps from the ASSP project were utilized to fill image voids over the southeastern portion of Afghanistan (See Figure 1).

AFGHANISTAN 1 : 100,000

# QANDAHAR

SHEET 2180




Scale : 1:100,000

1 0 1 2 3 4 5 6 7 Statute Miles

1 0 1 2 3 4 5 6 7 8 9 10 Kilometers

2000 0 2000 4000 6000 8000 10000 12000 Yards

UTM Projection Zone 42
International Spheroid
Landsat Thematic Mapper
Band 3 - Blue Band 7 - Green Band 4 - Red
30.0 meter resolution

NOTE: Image data has been georeferenced to the best available 1:100,000 scale maps.

Adjoining Sheets

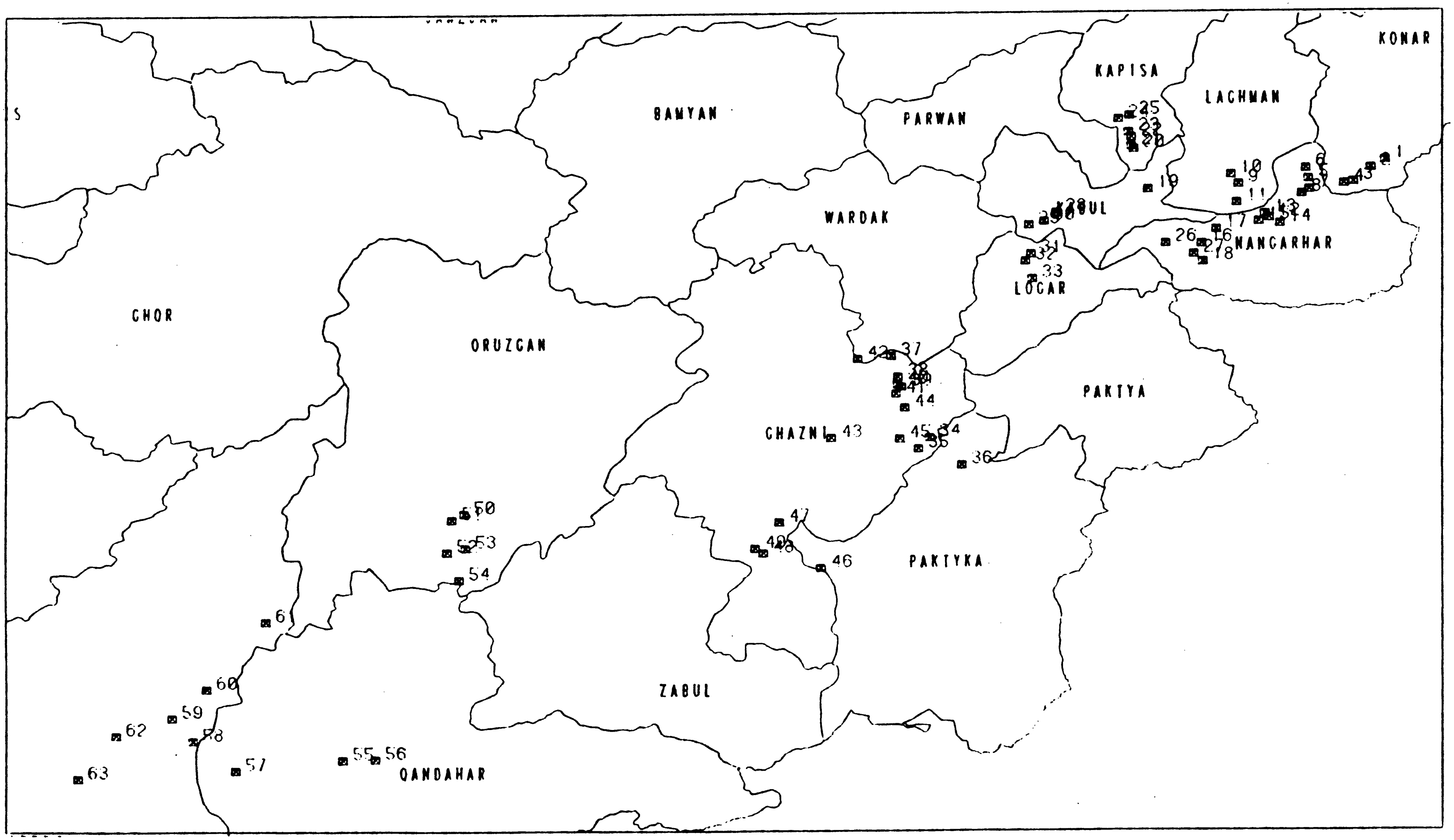
| | | |
|---|---|---|
| 2081 | 2181 | 2281 |
| 2080 | **2180** | 2280 |
| 2079 | 2179 | 2279 |

# APPENDIX B

# GROUND TRUTH SAMPLE POINTS AND SURVEY QUESTIONNAIRES

AFGHAN CROPCAST GROUND TRUTH SITES

REVISED 4 MARCH 1991



CROPCAST AFGHANISTAN GROUND TRUTH SITES
REVISED 01 MARCH 91

| No. | Latitude Degrees:Minutes:Seconds | Longitude Degrees:Minutes:Seconds | Latitude Decimal Degrees | Longitude Decimal Degrees | Map # | Province | Description |
|---|---|---|---|---|---|---|---|
| 1 | 34:44:02 N | 70:59:30 E | 34.73398 N | 70.99189 E | 3186 | Kunar | Along road |
| 2 | 34:41:36 N | 70:55:01 E | 34.69359 N | 70.91702 E | 3186 | Kunar | Road/Stream intersection |
| 3 | 34:37:10 N | 70:49:25 E | 34.61971 N | 70.82384 E | 3186 | Kunar | South side of River |
| 4 | 34:36:40 N | 70:46:24 E | 34.61116 N | 70.77339 E | 3186 | Kunar | Near Stream/River intersection |
| 5 | 34:38:10 N | 70:35:24 E | 34.63623 N | 70.59017 E | 3186 | Ningreha | Side Stream/North side of River |
| 6 | 34:41:28 N | 70:34:32 E | 34.69134 N | 70.57576 E | 3186 | Ningreha | Side Stream/North side of River |
| 7 | 34:34:49 N | 70:35:37 E | 34.58036 N | 70.59371 E | 3186 | Ningreha | Along Road at edge of Cultivation |
| 8 | 34:33:29 N | 70:33:17 E | 34.55831 N | 70.55494 E | 3186 | Ningreha | |
| 9 | 34:36:37 N | 70:13:23 E | 34.61050 N | 70.22322 E | 3086 | Laghman | Along side of River |
| 10 | 34:39:38 N | 70:11:00 E | 34.66068 N | 70.18349 E | 3086 | Laghman | Along side of River |
| 11 | 34:30:46 N | 70:12:50 E | 34.51294 N | 70.21397 E | 3086 | Laghman | Along Road at edge of Cultivation |
| 12 | 34:25:56 N | 70:22:58 E | 34.43240 N | 70.38287 E | 3085 | Ningreha | Along Canal South of Kabul River |
| 13 | 34:27:12 N | 70:21:46 E | 34.45354 N | 70.36279 E | 3085 | Ningreha | Along Canal South of Kabul River |
| 14 | 34:24:08 N | 70:26:28 E | 34.40223 N | 70.44113 E | 3085 | Ningreha | Along Canal near State Farms |
| 15 | 34:24:51 N | 70:19:45 E | 34.41442 N | 70.32918 E | 3085 | Ningreha | Along Canal near State Farms |
| 16 | 34:17:53 N | 70:01:41 E | 34.29807 N | 70.02828 E | 3085 | Ningreha | Along Stream |
| 17 | 34:22:22 N | 70:06:20 E | 34.37280 N | 70.10577 E | 3085 | Ningreha | Along Stream |
| 18 | 34:12:07 N | 70:02:09 E | 34.20210 N | 70.03609 E | 3085 | Ningreha | Between Streams |
| 19 | 34:35:08 N | 69:44:41 E | 34.58574 N | 69.74480 E | 2986 | Kabul | Along Stream near Lake |
| 20 | 34:47:53 N | 69:40:09 E | 34.79806 N | 69.66929 E | 2986 | Kapisa | Along Road at edge of Cultivation |
| 21 | 34:48:42 N | 69:39:28 E | 34.81181 N | 69.65795 E | 2986 | Kapisa | Along Road in Cultivated Area |
| 22 | 34:51:34 N | 69:39:21 E | 34.85972 N | 69.65591 E | 2986 | Kapisa | Along River in Cultivated Area |
| 23 | 34:53:07 N | 69:38:31 E | 34.88543 N | 69.64209 E | 2986 | Kapisa | Along Road at edge of Cultivation |
| 24 | 34:57:16 N | 69:35:12 E | 34.95460 N | 69.58691 E | 2986 | Kapisa | Along Road at edge of Cultivation |
| 25 | 34:58:20 N | 69:38:38 E | 34.97240 N | 69.64404 E | 2986 | Kapisa | Along River in Cultivated Area |
| 26 | 34:18:00 N | 69:50:18 E | 34.30000 N | 69.83850 E | 2985 | Ningreha | Along River |
| 27 | 34:14:35 N | 69:59:10 E | 34.24306 N | 69.98634 E | 2985 | Ningreha | Along River |
| 28 | 34:27:48 N | 69:15:17 E | 34.46342 N | 69.25479 E | 2885 | Kabul | Along River |
| 29 | 34:23:58 N | 69:06:39 E | 34.39953 N | 69.11095 E | 2885 | Kabul | South of Kabul |
| 30 | 34:25:02 N | 69:11:29 E | 34.41738 N | 69.19141 E | 2885 | Kabul | Southeast of Kabul |
| 31 | 34:14:46 N | 69:07:17 E | 34.24620 N | 69.12147 E | 2885 | Kabul | Along Road South of Kabul |
| 32 | 34:12:30 N | 69:05:34 E | 34.20834 N | 69.09293 E | 2885 | Lowgar | Along Road South of Kabul |
| 33 | 34:06:52 N | 69:07:45 E | 34.11462 N | 69.12929 E | 2885 | Lowgar | Along side of Road |
| 34 | 33:16:45 N | 68:35:01 E | 33.27944 N | 68.58382 E | 2783 | Ghazni | At Edge of Cultivation |
| 35 | 33:13:16 N | 68:31:24 E | 33.22136 N | 68.52355 E | 2783 | Ghazni | At Edge of Cultivation |
| 36 | 33:08:02 N | 68:45:13 E | 33.13399 N | 68.75364 E | 2783 | Ghazni | Along Road South of Lake |
| 37 | 33:42:36 N | 68:22:47 E | 33.71011 N | 68.37997 E | 2684 | Ghazni | Along River |
| 38 | 33:36:04 N | 68:24:52 E | 33.60138 N | 68.41452 E | 2684 | Ghazni | Between River and Road |
| 39 | 33:32:55 N | 68:25:59 E | 33.54865 N | 68.43315 E | 2684 | Ghazni | Along Road East of Ghazni |
| 40 | 33:33:41 N | 68:24:50 E | 33.56156 N | 68.41390 E | 2684 | Ghazni | Along Road North of Ghazni |
| 41 | 33:30:42 N | 68:24:15 E | 33.51168 N | 68.40420 E | 2684 | Ghazni | Along Road South of Ghazni |
| 42 | 33:41:44 N | 68:12:09 E | 33.69569 N | 68.20251 E | 2684 | Ghazni | Along side valley Stream |
| 43 | 33:16:44 N | 68:03:52 E | 33.27908 N | 68.06469 E | 2683 | Ghazni | Along Stream |
| 44 | 33:26:18 N | 68:27:04 E | 33.43834 N | 68.45122 E | 2683 | Ghazni | Center of Cultivated Area |
| 45 | 33:16:26 N | 68:25:26 E | 33.27410 N | 68.42405 E | 2683 | Ghazni | |
| 46 | 32:35:29 N | 68:00:40 E | 32.59162 N | 68.01136 E | 2682 | Ghazni | Along River |
| 47 | 32:50:10 N | 67:47:28 E | 32.83621 N | 67.79128 E | 2582 | Ghazni | Along paved Road (North side) |
| 48 | 32:40:19 N | 67:42:27 E | 32.67218 N | 67.70762 E | 2582 | Ghazni | Along River |
| 49 | 32:41:50 N | 67:39:52 E | 32.69743 N | 67.66457 E | 2582 | Oruzghan | |
| 50 | 32:53:09 N | 66:07:31 E | 32.88594 N | 66.12553 E | 2282 | Oruzghan | Along River |
| 51 | 32:51:14 N | 66:03:37 E | 32.85396 N | 66.06052 E | 2282 | Oruzghan | Along River |
| 52 | 32:40:58 N | 66:02:03 E | 32.68280 N | 66.03433 E | 2282 | Oruzghan | Along River at Bend |
| 53 | 32:42:16 N | 66:07:58 E | 32.70459 N | 66.13289 E | 2282 | Oruzghan | Along River at Fork |
| 54 | 32:32:08 N | 66:05:53 E | 32.53576 N | 66.09824 E | 2282 | Oruzghan | Along River |
| 55 | 31:34:54 N | 65:29:13 E | 31.58177 N | 65.48717 E | — | Qandahar | Between Road and River Arghandab |
| 56 | 31:35:05 N | 65:39:31 E | 31.58473 N | 65.65886 E | — | Qandahar | Southwest of City at edge of Mountain |
| 57 | 31:31:32 N | 64:54:55 E | 31.52563 N | 64.91538 E | — | Qandahar | North of River |
| 58 | 31:41:04 N | 64:41:24 E | 31.68469 N | 64.69020 E | — | Helmand | At Road intersection with Cultivated Area |
| 59 | 31:48:28 N | 64:34:40 E | 31.80791 N | 64.57780 E | — | Helmand | Just East of Greshk along Road |
| 60 | 31:57:41 N | 64:45:49 E | 31.96148 N | 64.76386 E | — | Helmand | Confluence of Helmand and side Wadi |
| 61 | 32:19:03 N | 65:04:36 E | 32.31754 N | 65.07674 E | — | Helmand | Downstream from Reservoir |
| 62 | 31:42:49 N | 64:16:50 E | 31.71381 N | 64.28065 E | — | Helmand | Along Canal North of Lashkar |
| 63 | 31:29:01 N | 64:04:39 E | 31.48385 N | 64.07770 E | — | Helmand | Along Canal |

QUESTIONS FOR PERSONS COMING OUT OF AFGHANISTAN
USE ONE FORM FOR EACH AREA VISITED. USE MULTIPLE FORMS IF NECESSARY.

1. Area visited and date:

______________________________________________

2. What was the overall condition of agricultural lands?
excellent___ good___ fair___ poor___

3. What were local people saying about this year's wheat harvest?
better than avg___ avg___ worse than avg___

4. What were the local people saying about the weather this growing season?
wetter than normal___ normal___ dryer than normal___

5. Type and condition of irrigation facilities? Type __________
Condition: fully operational___ some abandoned/damaged___
most abandoned/damaged___ not operational ___

6. Was there an irrigated wheat crop? Yes___ No___
Observed condition: excellent___ good___ fair___ poor___

7. Was there a rainfed wheat crop? Yes___ No___
Observed condition: excellent___ good___ fair___ poor___

8. Other crops observed and condition:

Crop:_______ Condition: excellent___ good___ fair___ poor___
Crop:_______ Condition: excellent___ good___ fair___ poor___
Crop:_______ Condition: excellent___ good___ fair___ poor___
Crop:_______ Condition: excellent___ good___ fair___ poor___

9. Evidence of infestations or crop disease of any sort?

Problem:_________ Condition: severe___ moderate___ slight___
How observed? visual___ verbal (word of mouth)___ other_____

Problem:_________ Condition: severe___ moderate___ slight___
How observed? visual___ verbal (word of mouth)___ other_____

10. Average price of wheat in area if known? __________

11. What problems were being talked about?

Drought___ Irrigation difficulties___ Pestilence___
Labor shortages___ Fertilizer shortages___ Other (Specify)

______________________________________________

DATE OF INTERVIEW:______________ INTERVIEWER:______________
Interviewer's assessment of reliability of information: good___ poor___
Page ___ of ___

## 2.0 CROP AREA ESTIMATION

### 2.1 Introduction

This section presents the methodologies used to estimate the area of wheat cultivation in Afghanistan for the 1990 harvest year. CROPCAST has used direct measurement of crop area from satellite imagery in other areas of the world with reliable results. The procedure was as follows: (1) identify (via literature research) the characteristics of the crop in the study area, including dominance, phenology, and farming methods; (2) from the information obtained in the literature search, define the best image acquisition time for each region of the country; (3) obtain, process, and photographically print suitable satellite imagery; (4) obtain input from knowledgeable persons and sources as to the spectral signature of the crop; (5) interpret the imagery for either total crop area, or for the specific crop if discernable; (6) summarize the interpretation results, and (7) utilizing information gained in the literature search and from knowledgeable persons, develop and apply reduction factors to account for wheat area as a percentage of annual crop area estimation on a regional basis.

The following sections describe two discrete methodologies which were used to provide an initial estimate of crop area based solely on historical data and knowledge of the current state of affairs in Afghanistan, and a final estimate based upon analysis of satellite imagery.

### 2.2 Analysis of Historical Information

Several sources were queried to provide background information on Afghan agriculture, and in particular, wheat cultivation. These sources included personal interviews with experts in Afghan agriculture, and a review of available literature. The interviewed persons included:

Dr. Mohammed Shah (Volunteers in Technical Assistance)
Dr. Abdul Wakil (consultant to Development Alternatives, Inc.)
Mr. Mohammed Bashir (University of Nebraska at Omaha)
Dr. Kenneth Langran (University of Nebraska at Omaha)
Dr. William Bergquist (consultant to Development Alternatives, Inc.)

March 5, 1991

## Afghan Ground Sample Question Set

1. Location, date and time.______________________________

2. When was crop planted? ______________________________

3. What is height of plants? ______________________________

4. What is the size of field? ______________________________

5. Is it all wheat? What else? ______________________________

6. Is crop rainfed or irrigated? ______________________________

7. Does crop look healthy? Any disease noted; etc? ______________

8. Are irrigation systems working? ______________________________

9. Is irrigation plentiful? ______________________________

Other comments:

The expert interviews focused on each interviwee's specialty relating to Afghan agriculture, and upon their knowledge of the current state of affairs (agricultural, political, demographic, etc.) in Afghanistan. These interviews yielded an invaluable pool of information not explicitly detected in literature sources.

In addition to the expert interviews, the libraries of the following institutions were queried:

Center for Afghan Studies (Arthur Paul Collection), University of Nebraska at Omaha (UNO), Omaha, NE
United States Agency for International Development (USAID), Rosslyn, VA
United States Department of Agriculture, Beltsville, MD
United States Library of Congress, Washington, DC
United States National Oceanographic and Atmospheric Administration (NOAA), Rockville, MD
University of Maryland McKeldin Library, College Park, MD

In general, literature on Afghan agriculture was very sparse. The best sources of information found were the expert interviews and the literature review at UNO. The latter revealed historic information on Afghan wheat production as reported by the Afghan government for the years 1960 through 1972, plus 1975, 1978, 1981, and 1982. Some of the information from these latter years was gathered during the war using survey methodologies outside Afghanistan, or originated with the besieged Kabul government, and are therefore considered less reliable than those from pre-war years. In terms of wheat production estimates, most of the data sources were national summaries. Only a very few differentiated the estimates by province, region, or crop.

There were conflicts between information provided by the expert interviews and that obtained from the literature. In particular, the interviewees who discussed Afghan Agricultural practices all reported that except in climatologically limited areas of irrigation, winter wheat was the principal crop, followed by a second (other) crop after the wheat harvest in May. This differed from the statistical literature sources, most of which predated the Afghan fertilizer programs of the 1970s, which implied that the land

area for each crop was exclusive, resulting in a simple sum total of cultivated area, against which statistics could be calculated for the "normal" area and production of wheat. Because of the insistence of the expert reports about crop rotation, EarthSat's approach was designed to calculate the total area cultivated in annual crops in the spring (March-May), assuming that a large percentage of this cultivated area would be wheat. It was hoped that late spring Landsat imagery would yield a satisfactory "picture" of the spring (rainfed) wheat crop as well. At the same time, research was conducted via the interviews and literature searches into percentages of expected crops, to provide a means of reducing total annual crop area to a figure representative of the wheat crop.

## 2.3 Preliminary Estimate of Wheat Area from Historical Data

Because a preliminary estimate was needed by the beginning of July 1990, and because difficulties were being encountered in obtaining satisfactory Landsat MSS imagery with which to conduct assessments of crop area, an alternate methodology was developed based upon the results of the literature search.

EarthSat's CROPCAST approach for crop yield forecasting for Afghan wheat utilizes computer modeling which takes into account the area of planted crop to arrive at a final assessment of crop yield as affected by various environmental factors. To calculate the amount of area planted in wheat, the following direct area measurement formula was to be used:

$$Ac = T_A - A_X - A_C + f$$

Where:

$Ac$ = Area of Crop
$T_A$ = Total area under cultivation
$A_X$ = Area not in agriculture (fallow or abandoned)
$A_C$ = Area in competing crops
$f$ = Factor to account for non-sampled areas

The variables for total area under cultivation, area not in agriculture, and area in competing crops were to be derived from measurements made of area from satellite

imagery already on order. This imagery was not available, however, at the time of the initial crop report required by the contract.

In order to provide a meaningful estimate of potential crop yield, a slightly different calculation of acreage based on non-visual inputs was utilized. This estimation of area was used to drive the computer model through the initial area calculation. As satellite imagery became available at a later date, the visual measurements described above were to be performed to improve the crop area (and therefore the yield estimation) assessments.

To arrive at the area under wheat in this format, the following formula was used:

$$A_{IW} = TA_A * C_W * C_D * C_C$$

Where:

$A_{IW}$ = Total Irrigated Wheat Area
$TA_A$ = Total Annual Crop Area (from Afghan statistics, 1973)
$C_W$ = Coefficient of Irrigated Wheat Dominance (<1.0)
$C_D$ = Coefficient of Irrigation Water Availability (<1.0)
$C_C$ = Coefficient of Competing Crops (<1.0)

The procedure for calculation of rainfed wheat area is as follows:

$$A_{RW} = TA_A * C_{RW} * C_R * C_C$$

Where:

$A_{RW}$ = Area of Rainfed Wheat
$TA_A$ = Total Annual Crop Area (from Afghan statistics, 1973)
$C_{RW}$ = Coefficient of Rainfed Wheat Dominance (<1.0)
$C_R$ = Coefficient of Area Reduction (from other sources) (<1.0)
$C_C$ = Coefficient of Competing Crops (<1.0)

Total wheat area is represented by the sum of $A_{IW}$ and $A_{RW}$.

Total acreage under cultivation and the reduction coefficients of wheat predominance, water availability, other reductions, and competing crops were estimated using the following foundations and assumptions:

# FINAL REPORT:

# SUMMARY OF DEVELOPMENTS FOR CROPCAST™ 1990 AFGHANISTAN WHEAT PRODUCTION ASSESSMENT

**Prepared for:**

**USAID/REP/P**
**Peshawar, Pakistan**

**and**

**Development Alternatives, Inc. (DAI)**
**Bethesda, Maryland, USA**

**DAI Contract 304-0204-C-00-9829-00**
**May 7, 1991**

**Prepared by:**

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# EXECUTIVE SUMMARY

The CROPCAST™ agricultural system was employed to assess the acreage under wheat cultivation and the potential yield for the 1990 Afghanistan wheat crop. Commercial satellite imagery was obtained and analyzed for approximately 50 percent of the country. The satellite data included Landsat Thematic Mapper (TM) and Multi-Spectral Scanner (MSS) images, TM image photomaps of southeastern Afghanistan prepared by EarthSat in the Agricultural Sector Support Program (ASSP) program at 1:100,000 scale, and a SPOT Multi-Spectral (XS) image. These images and image maps were used in the analysis of area of annual cropland by province. Statistics were calculated by province to account for non-wheat cultivation and non-agricultural inclusions in the delineated areas. The data were supplemented by expert opinion surveys and historical data bases to obtain information on traditional wheat areas and yield trends.

Climatological remote sensing data were obtained from the U.S. National Oceanographic and Atmospheric Administration's (NOAA) polar orbiting satellites in near real-time for use in monitoring environmental conditions for the 1990 crop. These data were analyzed and integrated into the CROPCAST agricultural monitoring system to provide province-level yield estimates for the Office of the United States Agency for International Development Representative (AIDREP) in Peshawar, Pakistan.

During the autumn of 1990, a snowpack monitoring model was employed to assess winter snowpack, potential irrigation, and potential flooding problems for the 1991 crop. Included in this report is a summary of 1991 wheat growing conditions as of April 30, 1991.

The CROPCAST data bases were transferred to an ARC/INFO Geographic Information System (GIS) for integration with other data bases to demonstrate the utility of the CROPCAST system in crop suitability assessments. A seminar was held at Earthsat offices on March 29, 1991 to demonstrate the various applications of the CROPCAST and GIS development during year one of the project.

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